STUDIES IN TECHNO-ECONOMIC FEASIBILITY OF AN AGRO BASE CANE-SUGAR-CUM-MAIZE STARCH COMPLEX

A Thesis Submitted
In Partial Fulfilment of the Requirements
for the Degree of
MASTER OF TECHNOLOGY

By

RAVI KELKAR

to the
DEPARTMENT OF CHEMICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

MARCH, 1979

CHE-1979-M-KEL-STU

21.3.79
Zi

CERTIFICATE

It is certified that the work entitled, 'STUDIES IN TECHNO-ECONOMIC FEASIBILITY OF AN AGRO-BASE CANE SUGAR-CUM-MAIZE STARCH COMPLEX', by Mr. R.K. Kelkar has been carried out under my supervision and it has not been submitted elsewhere for a degree.

J.K. Gehlaut

(J.K. Gehlaut)
Professor
Dept. of Chemical Engineering
IIT/Kanpur

MARCH 1979

ACKNOWLEDGEMENTS

The author is highly indebted to Dr. J.K. Gehlawat for his able guidance and timely suggestions.

The author wishes to acknowledge the help given by Mr. Arun Moharir and Shaunak Pawagi and Mr. Ramesh Kakwani in this work.

The author would also like to thank M/S D.K.Mishra, Buddhi Ram Kandiyal and Mr. B.S. Pandey for the drawing, cyclostyling and typing work of the manuscript.

Author

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Cane sugar industry is the second largest traditional industry in India. There are 272 sugar factories in operation throughout the country. Manufacture of maize starch is also an agrobased industry. There are eight maize starch factories in India. Sugars derived from starch through the process of hydrolysis such as malto-dextrins, liquid glucose and dextrose are valuable products. Presently textile industry is the major consumer of starch. Conversion of starch to sugars offers a great potential for large scale consumption in food products.

A study of the working of sugar industry reveals that it is a seasonal industry. The cane crushing season lasts for about 5-6 months in a year. The plant and the machinery remain idle for the rest of the period. The current sugar production is of the order of 60 lakh tonnes. The land under sugarcane cultivation would be around 25 lakh hectares.

Companion cropping of maize with sugarcane has been found to be successful. Recent reports have widely favoured a maize-sugar cane intercropping pattern. Hence maize and sugarcane may be produced simultaneously on the same farm. It may be interesting to visualize a situation wherein a sugar factory and a starch factory also coexist, that is, there is a cane sugar mill-cum-starch complex. In such a combination it will be possible to crush sugar cane in the season and maize in the off-season. Since maize can be stored

for long its crushing may be carried out throughout the year. Interestingly, some of the equipment and utilities such as boilers, electrical equipment, centrifuges and material handling equipment, a maintenance shop and storage space for products can be a common facilities. The capital investment for a new sugar factory with a crushing capacity of 1500-2500 tonnes of sugarcane per day is of the order of Rs. 6-7 crores. An additional expenditure of about Rs.1 crore (an increase of about 14-16 per cent) will add equipment to process about 100 tonnes per day of maize to obtain about 64 tonnes of maize-starch, 2.5 to 3 tonnes of maize oil, 3-4 tonnes of maize oil cake, 8 to 10 tonnes of maize gluten, 10 tonnes of maize bran and 5-6 tonnes of steep concentrate. The byproducts of maize processing are very valuable. Maize oil is among the best edible oils known so far. Oil cake, gluten, bran and steep concentrate are rich in protein and mineral matter. These products are useful ingradients of animal feeds. An animal-feed plant may be an integral part of the complex. Thus the proposed cane sugar-cum-starch complex will indeed become a multipurpose agro-base complex.

In view of the importance of such a large agro-base complex, a technoeconomic feasibility study was undertaken. It is found that such a project is highly profitable. Its implementation will be in the national interest.

INTRODUCTION

Manufacture of sugar as well as maize starch is an agro-based industry. In India sugar industry is second largest traditional industry. There are 272 mills in operation throughout the country. In Maharashtra State alone the number of operating sugar mills is over 50.

The sugar manufacture is a seasonal industry. A sugar mill operates for about 160 days in a year on an average. Consequently the plant and machinery remain idle during the off-season for about 200 days in a year. Most of the employees are laid off and the management potential is not fully utilized. Being a seasonal industry sugar manufacture suffers from the above mentioned disadvantages.

The manufacture of maize starch is another important agro-base industry. A large quantity of maize is grown in several parts of the country. It has been found that maize can be successfully intercropped with sugarcane. This in turn improves the earnings of the farmer considerably. Further, it appears feasible to have a multipurpose plant which will crush sugarcane during the season and process maize during the off-season. Such a combination is likely to form an interesting agro-base industry. Some of the machinery, essential services and management will be common for both

the units. The cost of installing a maize starch unit near an existing sugar mill is not very large. The techno-economic feasibility of such a combination of agro-base units is of national importance. Hence in the present work an attempt has been made to carry out a techno-economic study of a maize starch-cum-cane sugar mill.

A CASE FOR A CANE SUGAR-CUM-MAIZE STARCH COMPLEX

The sugar industry as well as starch manufacturing unit, both are agro-based industries. Cane sugar is a disaccharide commonly known as sucrose. The sugar obtained on hydrolysis of starch is glucose - the monosaccharide which is the direct energy for human system. It is for this reason that a larger portion of the daily human diet consists of starches (source: wheat, rice, potato, bread and vegetables). This starch eventually gets converted into sugars in the human digestive system. It is logical to consider a situation in the near future when starch sugars may be preferred over the conventional cane sugar for human consumption. The trend in the developed countries is already favourable to starch sugars.

A study of the working of the traditional sugar industry clearly reveals that it is a seasonal agro-based industry. The cane crushing season lasts for 5 to 6 months. The sugar industry remains idle for the remaining period.

An intercropping pattern of growing maize and sugar cane in the same piece of land has been found to be successful. The increase in the amounts of inputs in the form of water, fertilizers and supervision is marginal. The yield of maize has been found to be about 1.5 to 2.5 tonnes per hectare of

land under sugarcane cultivation without seriously affecting the yield of sugarcane. This additional yield of maize may be considered as a bonus cash crop. Indeed, intercropping of maize with sugarcane may be considered as a real break-through in agricultural practice. If intercropping be carried out on massive scale it may be possible to produce about 15-20 lakh tonnes of additional or bonus maize without increasing land under the maize crop. This will amount to an increase in the annual output of maize by about 20 per cent. The current annual production of maize in India is of the order of 77 lakh tonnes.

It may be interesting to visualize a situation wherein a sugar factory and a starch factory coexist, that is, there is a canesugar mill-cum-starch complex. The factory will crush cane in the season and maize in the off-season. Storage of maize is no problem. It can be stored and preserved for long. Interestingly, some of the equipment and utilities such as boilers, electrical installations, centrifuges and material handling equipment a maintenance shop and storage space for products can be common facilities. If a starch unit is attached to an existing sugar factory, the savings in its capital costs will be as shown in Table 1.

As discussed elsewhere, the capital investment for a new sugar factory with a crushing capacity of 1500-2500 per day may be of the order of Rs.6-7 crores. An additional

expenditure of about Rs.1.0 crore (an increase of about 15-16 per cent only) will add equipment to process about 100 tonnes per day of maize to produce about 64 tonnes of maize starch, 2.5 tonnes of maize oil, 3.5 tonnes of oil cake, 10 tonnes of maize gluten, 10 tonnes of maize bran and 5 tonnes of steep concentrate. The byproducts of maize processing are very valuable. Maize oil is among the best known edible oils so far. Oil cake, gluten, bran and steep concentrate are rich in protein and mineral matter. These products are useful ingradients of animal feeds. An animal-feed plant may be an integral part of the complex. It may also have a liquid glucose and dextrose unit. There may be units for the manufacture of chemicals and other products based on starch, sugars, molasses and bagasse. Thus, the proposed cane-sugar-cum-starch complex would indeed become a multipurpose agro-base complex similar to the present petrochemical complexes.

It would emerge from the above discussion that a combination of a traditional sugar factory with a maize starch unit may prove advantageous. It is likely to result in substantial cost savings which would mean lower costs of production for the starch as well as cane sugar.

TABLE 1

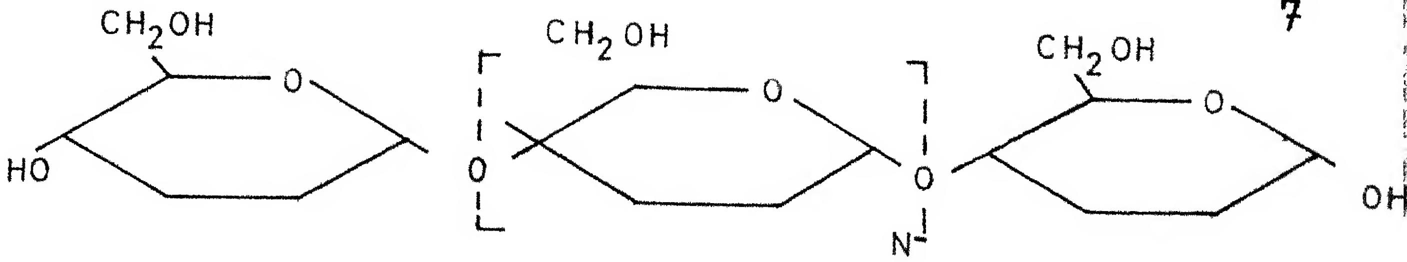
COMMON UNITS FOR STARCH AND SUGAR FACTORY

S.No.	Common Units/Accessories	Rs.
1.	A 20 tonne weigh bridge and a 500 kg other weigh scales	50,000.00
2.	Non clogging centrifugal pumps (20 numbers of different sizes in S.S. or bronze construction)	2,00,000.00
3.	Material handling equipment (conveyers, elevators etc.)	1,00,000.00
4.	Water ring type vacuum pump	50,000.00
5.	Sulphur burning equipment	50,000.00
6.	Workshop machinery for maintenance	1,00,000.00
7.	Laboratory apparatus	1,00,000.00
8.	Fire fighting equipment	2,50,000.00
9.	Boiler	5,00,000.00
10.	Sub-station and electric equipment	2,00,000.00
11.	Land	2,00,000.00
12.	Buildings (godowns) etc.	3,00,000.00
	Rs.	21,10,000.00

Total cost of new starch plant is estimated at Rs.1.50 crores.

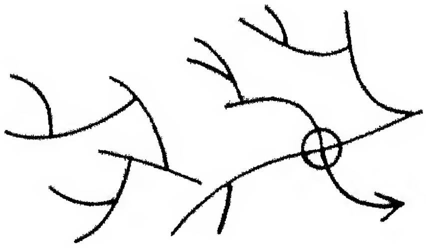
The money saved in installing a new starch plant along with a sugar plant

$$= \frac{21,00,000 \times 100}{1,50,00000} = 14.0 \text{ per cent}$$

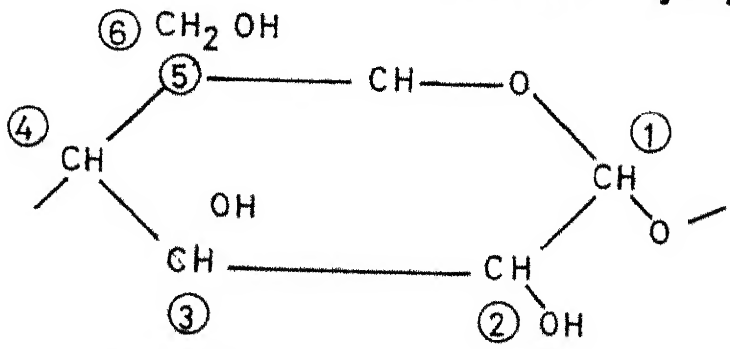


(Linear fraction N = 400-2000)

AMYLOSE



Branched fraction(Amylopectin)



Anhydro glucose unit

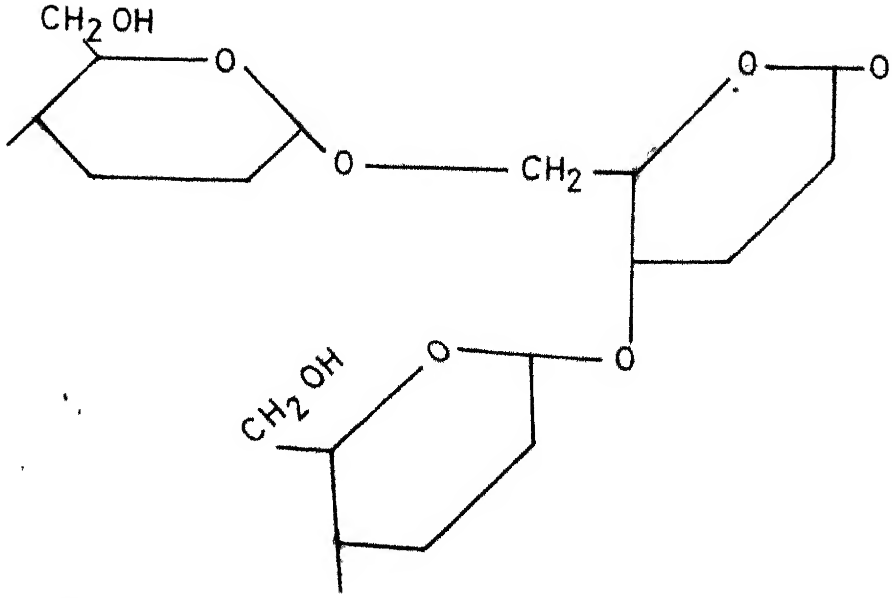


Fig. 1 Chemistry Of Starch

STARCH OF SUGAR AS POTENTIAL SOURCE OF ORGANIC CHEMICALS

Starch is one of the few naturally occurring high polymeric substances which could be the source of a large number of industrial products [1]. Its conversion products such as dextrose and ethyl alcohol could provide an almost inexhaustible source for the manufacture of organic chemicals. The economic future of starch lies more in the manufacture of chemicals based on it at a lower cost than on its availability. Some aspects of starch and related products in India have been discussed in several recent publications [2-4].

Starch is a natural polymer made up of anhydro glucose units. Two types of polymers may be found in starch as shown in Figure 1. The linear fraction known as amyloze is made up almost exclusively of α 1,4 linkages and the branched polymer called amylopectin contains, in addition to the predominent α 1,4 linkage, occasional branches at the 6 position in which the branches are joined to the parent molecule via α 1,6 linkages. The degree of polymerization (DP) will vary within a given starch and the average depends upon the plant from which it is derived. In general the average DP runs from 400 to 2000 depending upon type of the starch. Each anhydroglucose unit in the starch polymer contains one primary and two secondary alcoholic groups. Therefore,

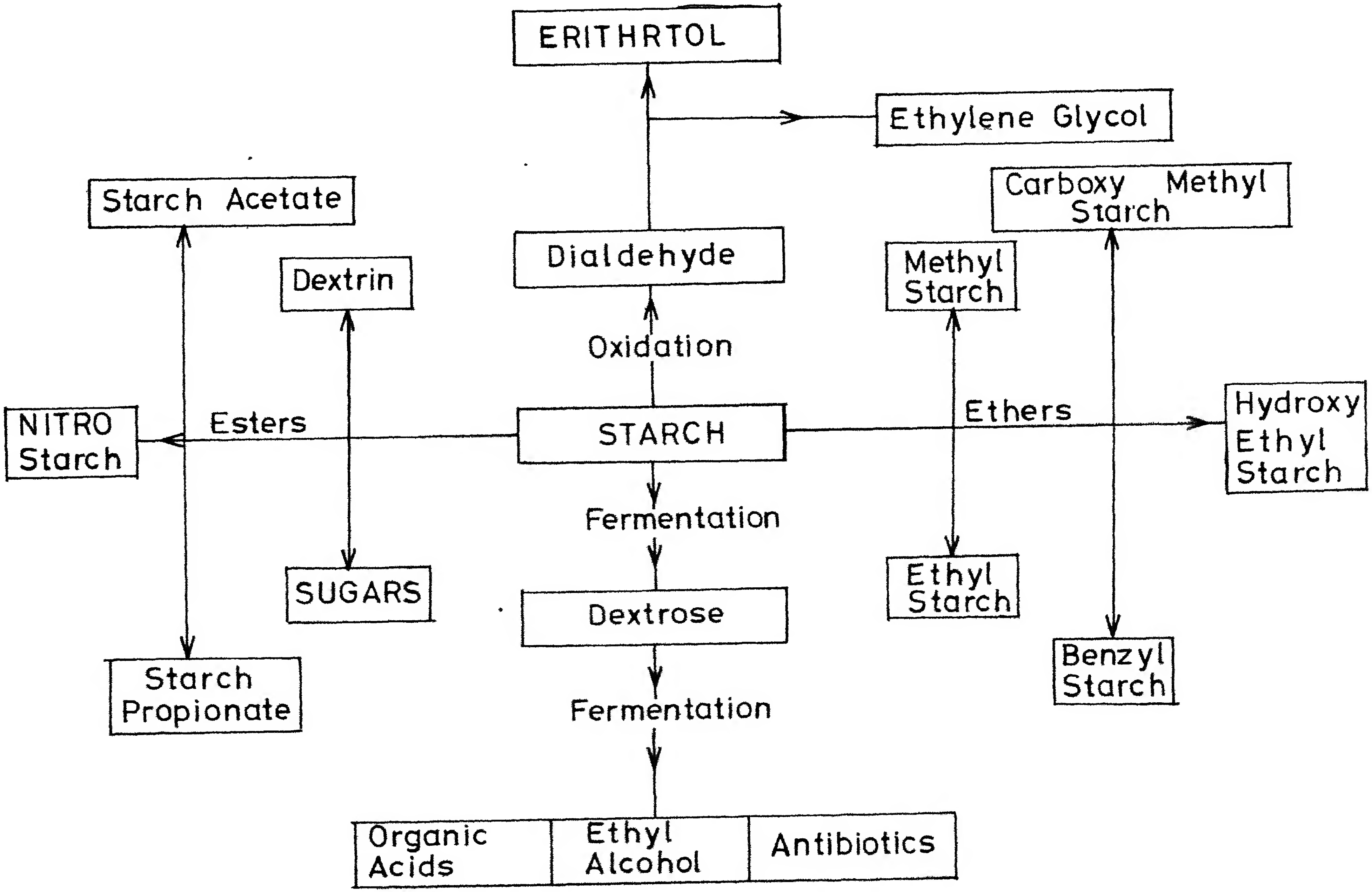


Fig.2 Starch Derivatives

starch and its derivatives can take part in a number of chemical reactions to produce a host of new products, as may be noted from Figure 2.

Chemistry of Sugar:

Chemical Formula:

$$C_{12}H_{22}O_{11} \text{ (disaccharide)}$$

Structural Formula

O

$CH_2OH-CH-CHOH-CHOH-CHOH-CH-O-C-CHOH-CHOH-CH-CH_2OH$

O

CH_2OH

Sucrose is a disaccharide composed of D-glucose and D-fructose. It is said to be the first pure carbohydrate to separate from the photosynthetic process. It is found in almost all land plants, in the juice, seeds, flower, leaves, stems and roots.

It is nonreducing and it can be readily hydrolysed. Fermentation and other dehydrations of sucrose are the most important industrial (non -food) applications.

$$\text{Sucrose} \xrightarrow[\text{Enzymes}]{\text{Acid hydrolysis}} \text{D-glucose + D-Fructose}$$

(Invert sugar)

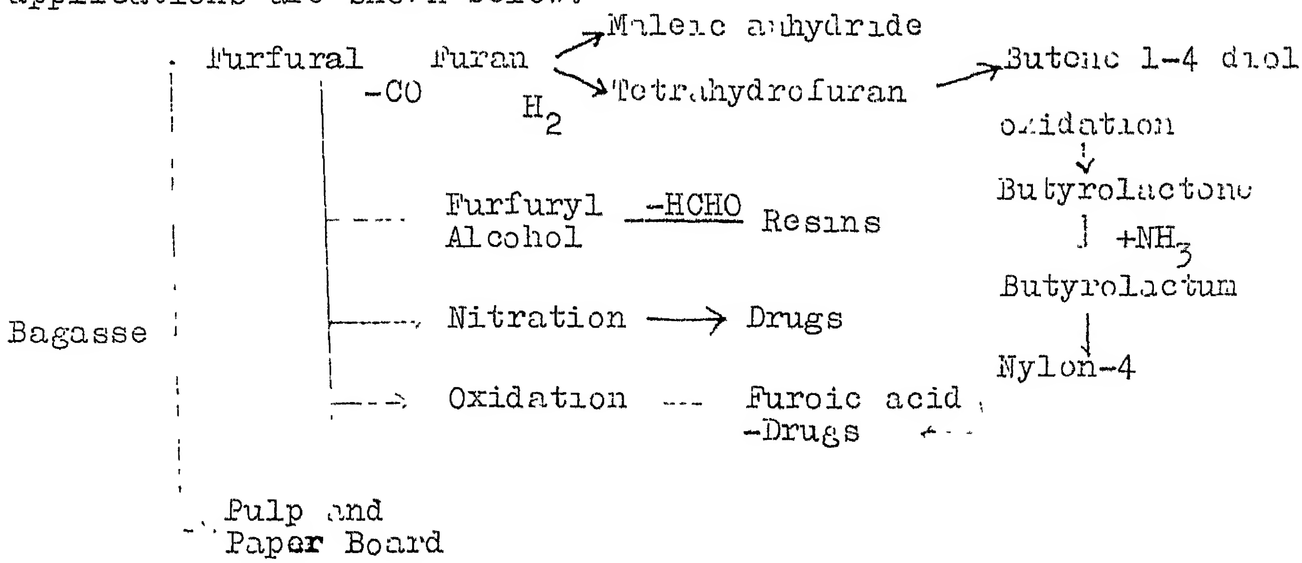
Alcohol and bagasse are the major by-product of sugar industry. By various processes these two byproducts can yield an impressively wide variety of industrial chemicals.

As shown below the useful applications of molasses are depicted.

Molasses

- ———— Animal feed-staff and for manure
- Yeast fermentation ———— Ethyl alcohol
- Bacterial fermentation ———— 1-butanol and acetone, 2,3 butanediol, propionic acid, butyric acid
- Yest fermentation in presence of sodium sulphite or Na_2CO_3 ———— Glycerol
- Oxidation (permangnate or nitric acid ———— Oxalic acid
- ————As a flavouring agent in tobacco
- Ammonium mobdate, sulphuric acid (ethyl alcohol) ———— dyes [ranging from light green to dark blue]
- ———— As a road surfacing material Plas-Mo-Flat

The crushed remnants of sugarcane stalks from which sugar containing juices have been extracted are known as bagasse. The usual composition of bagasse from the mill is 45 per cent insoluble solids or crude fibre, 6 per cent soluble solids and the remainder moisture. Its many industrial applications are shown below:



The technology of furfural aldehyde [24] production from bagasse is very well developed in western countries, it is produced from variety of agricultural waste including rice husk, penuthulk, bagasse, corn cob etc.

The approximate investment for a plant to produce 6000 tonnes of furfural aldehyde and 1,800 tonnes of acetic acid by product is Rs.8-10 crores. The plant would consume about 22 tonnes of raw bagasse/tonne of furfural produced. Of this about 20 tonnes can either be used for paper making or can be returned to sugar industry to be used as fuel.

Sugarcane as well as maize are among the most efficient biological converters of solar energy. When fully developed this agro-based industry can meet the country's chemical and energy needs at much lower cost by the end of the current century when the presently known oil resources are likely to be exhausted.

MAIZE STARCH INDUSTRY

Maize is an agricultural product and can be produced in large quantities. Presently in some parts of India two crops of maize are grown in a year but it appears possible to increase the crop cycle to three in a year in certain regions. It takes about 100 days for the crop to be ready. Table 2 shows the production of maize in India during the decade 1967-1977.

TABLE 2

PRODUCTION OF MAIZE IN INDIA

Year	Quantity in lakh tonnes	Remarks
1967-68	62.7	In India presently about 3,00,000 tonnes of maize may be used for starch manufacture. This comes to about 5 per cent of the total production of maize in the country. Balance quantity is used for human consumption and for animal feeds.
1968-69	57.0	
1969-70	56.7	
1970-71	74.8	
1971-72	50.2	
1972-73	62.0	
1973-74	65.0	
1974-75	68.5	
1975-76	72.6	
1976-77	75.0	

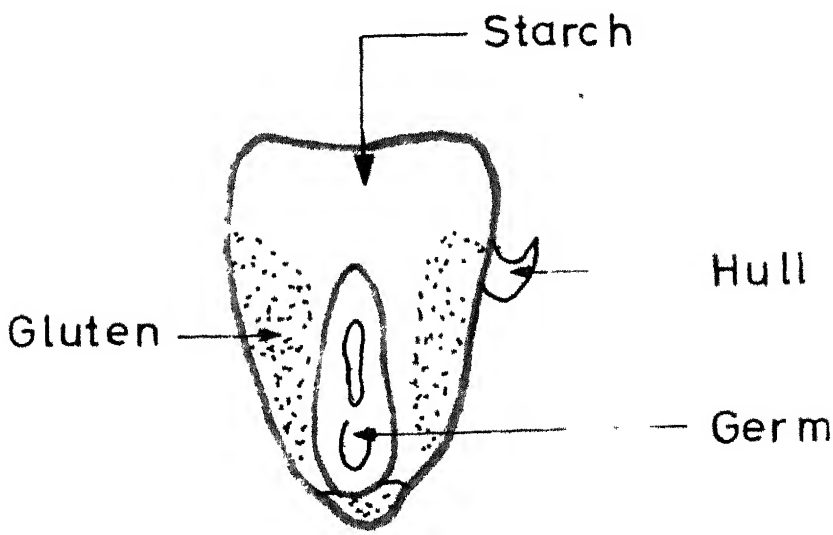


Fig. 3 Kernel Of Maize

The maize kernel is indeed a wonderful gift of nature to mankind. A look at the maize kernel (Figure 1) would show that it is composed of four constituents. They are termed as (i) Germ; (ii) Fibre (hull); (iii) Gluten (Proteinous material) and (iv) starch. The term of embroy, is an elongated oval shaped portion with one end at the tip of the Kernel. It contains most of the oil, and much of the protein, solubles, sugars and ash. The side portions of the maize kernel are yellowish, hard and horny and somewhat translucent. They contain most of the gluten, the primary protein constituent of grain, and a minor portion of the starch. The remainder of the kernel is white and almost powdery. This is primarily starch. The kernel is covered by a fibrous layer of hull, nature's protection for the valuable contents.

A variety of maize are grown on the farm. Recently high yielding varieties of maize have been developed through the process of hybridization. By virtue of its high starch content and unlimited storage life, maize is a raw material most suited for starch processing. Moreover, a number of valuable by-products can be obtained. In fact maize can be effectively utilized to nearly 100 per cent of its constituents. All kinds of maize are suitable for the production of starch. However, hybrid maize is considered more suitable for industrial processing than the ordinary variety. The distribution of various constituents of maize (depending on the variety) is

approximately as follows [1]. Starch 60-70 per cent; protein 9-10 per cent; oil/fat 2-4 per cent; fibre 8-10 per cent; mineral matter about 1 per cent; moisture 12-16 per cent.

Process for the Manufacture of Maize Starch and Derivatives [5,6]

The production of maize starch is achieved by the standard wet-milling process. This process is common throughout the world with minor variations. There are four principal steps in this process (i) steeping; (ii) grinding; (iii) fibre separating and (iv) product recovery. These are shown in the accompanying general process flow chart in Figure 4.

Maize either from storage or as received from market, it cleaned and transferred to large steeps (steeping vats). Here a hot aqueous solution containing dissolved sulphur dioxide (called steep water) is pumped in a counter current manner through the maize steeps. During this treatment the maize kernels imbibe water and swell to their maximum size. The steeping solution removes soluble components from the kernels and loosens the starch from the protein matrix in which it is embedded. The steep water is then drawn off, concentrated in multieffect evaporators to about 50 per cent solid content. The steep concentrate is sold as a constituent of cattle feed and as a nutrient in the manufacture of antibiotics such as penicillin.

The maize after proper steeping is conveyed to degerminating mills where the soft, swollen kernels are broken

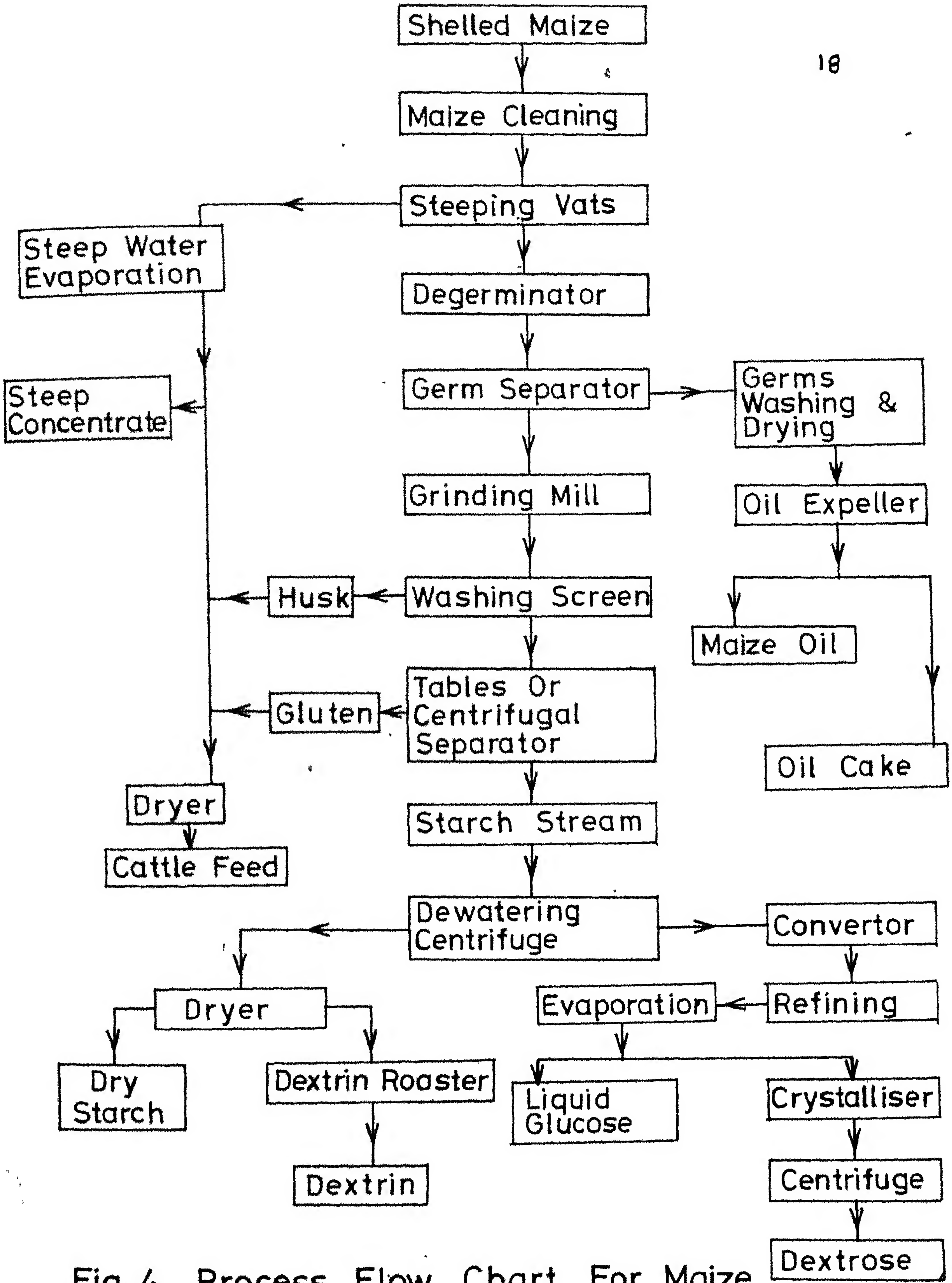


Fig. 4 Process Flow Chart For Maize Starch & Derivatives

and disrupted to release the germs. The germs thus released from the whole grain are recovered by germ separators and are washed free of starch. The germs are dried and crushed in oil expellers to obtain maize oil and oil-cake both of which are highly valuable byproducts.

A second grinding step of the germ-free partially broken maize kernels releases the starch from the hull and fibre. It is called fine milling. A system of screens, filters and washing devices separates the hull and fibre from the starch and gluten. Finally the starch and gluten are separated by the method of tabling (old practice) or by centrifugal separators or by hydroclone separators (modern method). The fraction containing gluten is put through filter presses, and dried. Gluten is rich in protein and is used for cattle feed. The fraction containing pure starch is dewatered, centrifuged and dried in a flash dryer. The starch may be sold as such or it may be further converted into dextrins, syrups, dextrose and other industrially useful derivatives.

Process of Manufacture of Liquid Glucose:

Starch is hydrolysed to form glucose in the presence of catalysts. The basic reaction may be represented as follows:

$$\underset{\text{Starch}}{(C_6 H_{10} O_5)_n} + \underset{\text{Water}}{n\ H_2O} \xrightarrow[\text{Heat}]{\text{Catalyst}} \underset{\text{Glucose}}{n\ C_6 H_{12} O_6}$$

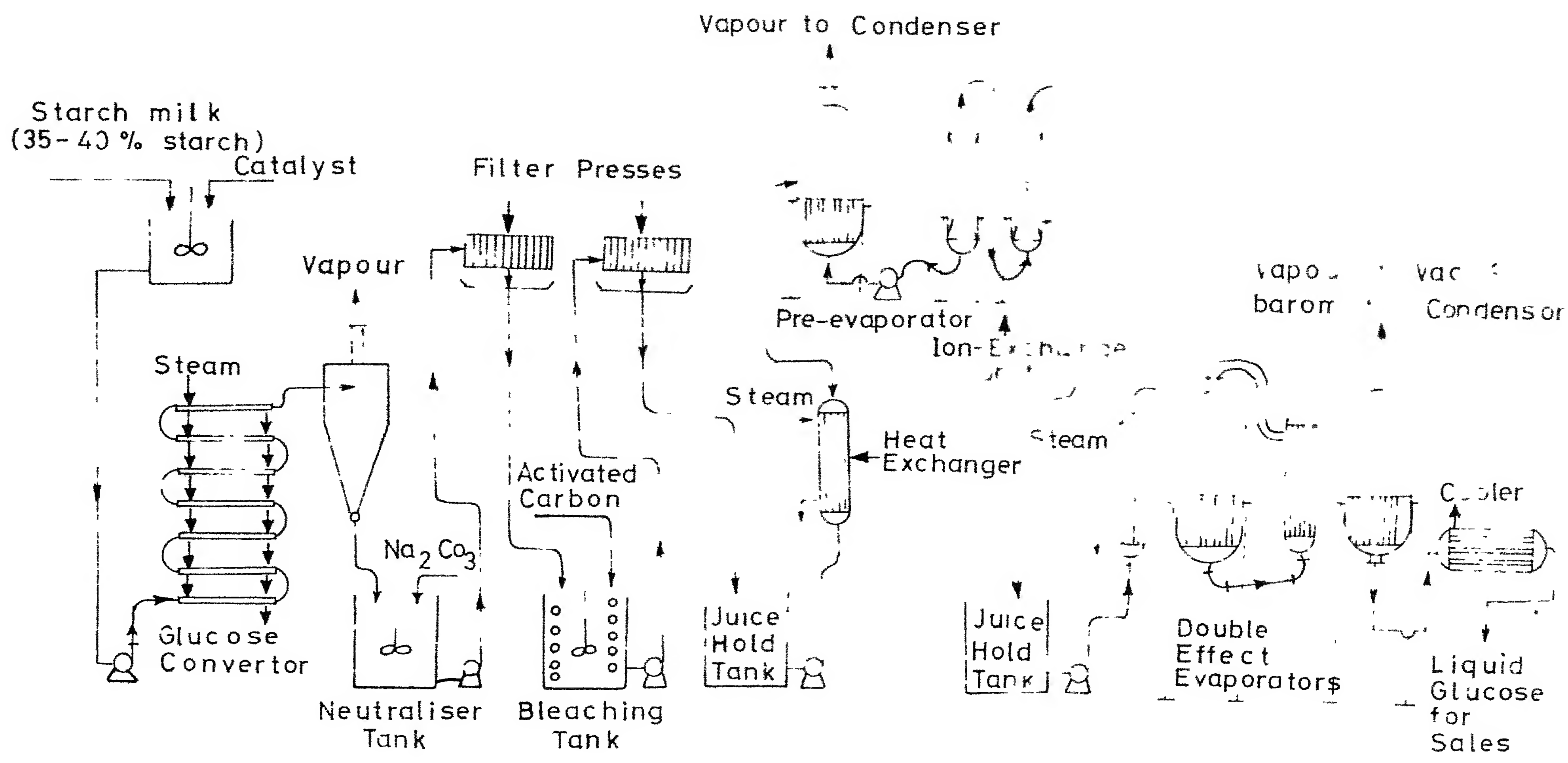


Fig. 5 A Schematic Process Flow Sheet for Liquid Glucose Manufacture

The process for the manufacture of liquid glucose from Starch is therefore a one step process. The glucose formed as above is suitably purified, refined and recovered as a viscous syrup which is the acceptable form for many industrial applications. The various stages of the process are illustrated in the accompanying flow diagram.

Well refined starch containing less than about 0.3 per cent protein is made into a slurry in water in a stirred tank and its concentration is adjusted to about 35 per cent solids. A required quantity of hydrochloric acid (approximately about 0.2 per cent) is added as the catalyst. The slurry containing the acid catalyst is pumped through a continuous coil type tubular reactor of suitable design at the desired flow rate and temperature. The products of the reaction (essentially glucose) are received from the reactor into a flash tank. The hot dilute juice is transferred to a neutraliser where excess acid is neutralised by its reaction with sodium carbonate. An activated carbon treatment is then carried out followed by filteration of the treated juice. The juice from the filter presses is sent through a system of ion-exchange resins where it is made free of any contamination with mineral salts. The demineralized juice is sent to a pre-evaporator for concentration wherein the solid content is increased from about 40 per cent to about 60 per cent. At this stage a second treatment of activated carbon may be given to

completely decolurise the partially concentrated juice.

It is then put through the final double effect evaporator operated under vacuum where the solid content in the syrup is increased to about 82-84 per cent. The syrup from the final evaporator is cooled in a mechanical cooler and filled into drums for despatch.

The starch stream is further purified by washing. It is dewatered, centrifuged and dried to obtain the main product starch which can be sold as such or converted into dextrins, syrups (liquid glucose), dextrose and other useful industrial products.

General Statement of Plant Requirements:

(a) Capacity:

The consideration of plant capacity is influenced by the minimum economic size of the plant and by the demand for the products. From such a consideration and from experience of existing units, the proposed plant should have a maize crushing capacity of 20,000 tonnes of maize to produce about 12,000 tonnes of maize starch per year. Since the demand for starch products is expected to increase, provision must be made in the layout and at the premises for future expansion.

(b) Space Requirements:

(i) Storage facilities for raw material (maize) and finished products (godown type construction) will

require a floor area of about 4,000 square meters.

(ii) The process house (which will be partly a multistorey building) will require a floor area of about 1,500 square meters.

(iii) A built in area of about 1,500 square meters will be required for workshop, boiler house, plant stores and the administrative blocks.

A provision for future expansion has to be made. It is also desirable to have a plot reserved for a demonstration and experimental farm for the maize development programme. This will illustrates to the local farmers the use of better seeds and better farming techniques to produce more maize per acre.

From the above considerations a plot of about 15 acres should be purchased.

(c) Power Requirements:

The published literature and the experience of existing units indicate an average figure of 18-25 H.P. installed per ton of maize crushed. The capacity under consideration an installed load of 1000 kVA should be adequate.

(d) Coal/Fuel Requirement:

In view of the fuel crisis, only coal fired boilers can be considered. In practice about two tonnes of steam are required per ton of maize processed. For a daily crushing

capacity of about 60 tonnes of maize, the steam requirements work out to about 100 tonnes per day or approximately 5 tonnes per hour. The boiler capacity should therefore be taken as 5 tonnes of steam per hour. Adequate space for storage of coal should be provided.

(e) <u>Water Requirements</u>:

Maize starch manufacture is a wet process wherein plenty of water is used as a medium or vehicle. In practice the requirement of water is found to vary between 3 to 5 m^3 per ton of maize processed. Taking an average figure of 4 m^3 per ton of maize, for a daily crushing capacity of 50 tonnes of maize, the water consumption would come to 2,00,000 l/day.

(f) <u>Waste Disposal</u>:

For a completely bottle up process, wherein fresh water is fed only at the final refining stage and all process water leaving different dewatering stages is fed back to the process and when steep water is fully recovered as steep concentrate, the effluent disposal is not a serious problem. The effluent disposal becomes a health hazard if steep water is not fully recovered or if the effluents contain dissolved organic matter beyond a prescribed limit. Effluent treatment will then be necessary.

(g) Based on the above general considerations, a plant and site layout is suggested in Figure 6.

(h) Stagewise List of Equipment with Specifications and Costs:

The following list of equipment in Table 3 is based on plant experience and guidelines as indicated in the literature. The specifications are broad out but considered adequate for a preliminary project design.

TABLE 3

STARCH UNIT EQUIPMENTS

Stage of Process	Description of Machine	Quantity	Estimated Cost
1. Maize receiving and cleaning	a. Weighbridge 20 tonnes capacity	1 No.	Rs. 50,000.00
	b. Weight/scales 500 kg	2 Nos.	10,000.00
	c. Bucket elevator-8" bucket size and 25' height	1 No.	10,000.00
	d. -do- 50' height		15,000.00
	e. 10" size screw conveyor-50' long	2 Nos.	20,000.0C
	f. Grain cleaning machine capacity 5 tonnes/hr	1 No.	30,000.0(
2. Steeping of Maize	Steeping vats 3M dia x 6 M		
	a. Height (RCC construction)	8 Nos.	150,000,0(
	b. Non-clogging centrifugal pumps in bronze construction, 500 l.p.m. and 30M head	8 Nos.	80,000.0C

3. Coarse Milling	a. Coarse Grinders 36" size	2 Nos.	20,000.00
	b. Germ separators-wooden trough type construction 2M x 6M size	2 Nos.	30,000.00
	c. Germ washing tank (wooden 3000l capacity).	2 Nos.	10,000.00
	d. Germ Press (screw press type)	1 No.	10,000.00
	e. Feed vibrators(shaking sieves)	4 nos.	15,000.00
	f. Centrifugal pumps in bronze construction, non-clogging type, 600 lpm 40 M head	2 Nos.	25,000.00
	g. -do- 300 lpm and 25M head	2 Nos.	15,000.00
4. Fine Grinding and Fibre Washing	a. Fine grinders-36" size	3 Nos.	40,000.00
	b. Feed vibrators	3 Nos.	15,000.00
	c. Wooden tanks-3000l	3 Nos.	15,000.00
	d. Slit screens	6 Nos.	1,50,000.00
	e. Pumps non-clogging type, bronze, 600 lpm and 40M head	7 Nos.	90,000.00
	f. Fibre-press	1 No.	10,000.00
5. Gluten and Starch Separators	a. Centrifugal separators of adequate capacity or hydroclove separators	2 sets	20,00,000.00
	b. Pumps and wooden tanks (as per requirement)	-	50,000.00
6. Dewatering and Drying of starch	a. Horizontal basket, continuous type centrifuge of matching capacity	1 No.	4,00,000.00
	b. Starch dryer(flash type) 40 ton/day starch capacity	1 No.	2,50,000.00
	c. Wooden tanks 3000 l	2 Nos.	10,000.00

7. Dewatering and drying of gluten	a. Flash dyer 6 tonnes/day	1Nos.	1,50,000.00
	b. Plate and frame type wooden filter press as 36" x36" -30Nos.plates	4Nos.	80,000.00
	c. Pumps	2Nos	15,000.00
	d. Wooden tanks 3000 l	2Nos.	10,000.00
8. Germ Dryer and Oil Expellers	a. Germ dryer (rotary steam tube type) 4tonnes/day		1,50,000.00
	b. Oil expellers (matching capacity)	2Nos.	40,000.00
	c. C.I.plate and frames (with pumps)	2Nos.	20,000.00
	d. 6" size Bucket elevator and 10" size screw conveyor	1set	20,000.00
9. Steep Evaporators	a. Double effect evaporators in stainless steel construction of matching capacity	1set	10,000,000.00
	b. Water-ring type vacuum pump	1No.	30,000.00
	c. Wooden tank 5000 l	1No.	5,000.00
10. Sulphur burning section	a. Sulphur burner, 300 kg/day capacity	1No.	35,000.00
	b. Airblower/compressor 2,500 lpm	1No.	20,000.00
	c. Absorption tower	1set	25,000.00
	d. Pumps, bronze construction	2Nos.	20,000.00
11. Packing section	a. Starch sifters 2tons/hr capacity	2Nos.	25,000.00
	b. Elevator conveyor	1set	20,000.00
	c. Weight scales 250 kg	2Nos.	5,000.00

12.	A 20 ton/day capacity complete liquid glucose unit		30,00,000.00
13. Misc. equipment	a. Boiler-coal fired 5000 kg/hr steam at 12-15 kg/cm^2	1 No.	5,00,000.00
	b. Transformer-1000 kVA with accessories	1 No.	1,00,000.00
	c. Electric cables, Switchgear, motor control centres, starters and capacities		5,00,000.00
	d. Electric meters (not included with equipment)		2,00,000.00
	e. Steam pipes and fittings		2,00,000.00
	f. General valves, process piping and fittings		2,50,000.00
	g. Workshop equipment-lathes, drilling machiner, griders welding sets etc.		50,000.00
	h. Structurals and steel plates		1,50,000.00
	i. Storage tanks for maize oil, water bother services		1,00,000.00
	j. Insulation and erection expenses		3,50,000.00
	k. Fire-fithting equipment		2,50,000.00
	l. Laboratory and Office equipment		1,00,000.00
	m. Contingencies		5,00,000.00
Therefore total cost of Plant and Equipment			1,13,90,000.00

<u>Land and Building</u>:

(a) <u>Land</u>: 15 acres of developed plot — Rs.2,50,000.00

(b) <u>Buildings</u>: The cost of construction of buildings, roads and drainage is estimated at — Rs.20,00,000.00

Pre-operative Expenses:

Misc. expenses to be incurred during the construction period (appr. two years) and to be capitalized Rs. 5,00,000.00

Total Capital Investment:

It is sum total of equipment cost, cost of land and buildings and Pre-operative expenses. This amount to Rs.1,55,00000. (Rs. One Crore Fifty Five Lakh)

Working Capital:

Working capital generally comprises of the funds needed for the payment of wages, service requirements, packing materials, general stores, the cost of raw materials, fuel etc. for a given period say for a period one months or two depending upon the trade credit facilities to be provided. The amount needed for a crushing rate of 1000 tonnes of maize per month would be as follows (Table 4).

TABLE 4

(1) 3 months stock of Maize: 3000 tonnes at Rs.1000 per tonne	Rs.30,00,000.00
(2) Sulphur: 10 tonnes at Rs.1000 per tonne	Rs. 10,000.00
(3) 2 months credit for finished product (starch): 1250 tonnes at Rs.2,200 per tonne	Rs.27,50,000.00
(4) One months salary and wages	Rs. 1,00,000.00
(5) One months expenses for Utilities - power, steam (coal) and Water	Rs. 1,50,000.00
Total:	Rs.60,00,000.00

Cost of Manufacture:

The cost of manufacture comprises of all expenses incurred in running the project and includes interest on borrowed capital, expenses on sales, depreciation on plant and machinery and insurance on total block.

The proposed installed capacity of the plant is about 20,000 tonnes of maize per year or about 1600 tonnes/month. The following estimates for the cost of manufacture are considered for a crushing rate of 1000 tonnes of maize per month. The comes to about 60 per cent of the installed capacity.

TABLE 5

STARCH UNIT: MONTHLY PRODUCTION EXPENDITURE

Expenditure:	
1. Raw Material	
(a) Maize 1000 tonnes at Rs.1000 per tonne	Rs.10,00,000.00
(b) Sulphur 5 tonnes at Rs.1000 per ton	5,000.00
2. Wages (labour and supervision)	70,000.00
3. Depreciation	
(a) 15 per cent on plant and machinery	1,25,000.00
(b) 5 per cent on buildings	20,000.00
4. Utilities: Power, fuel, water etc.	1,72,000.00
5. Packing cost: gunny bags, drums etc.	1,00,000.00
6. Repairs and maintenance	20,000.00
7. Insurance on total block	10,000.00

8. Interest on borrowed capital: term loans, bank loands and deposits/loands from public — 1,75,000.00

9. Administrative and selling expenses appr. at 5 per cent on sales — 85,000.00

Therefore Total Cost: Rs.17,82,000.00

Sales:

The revenue is calculated for crushing rate of 1000 tonnes maize per month at the given recovery level of various products.

TABLE 6

GROSS SALES FOR A CRUSHING RATE = 1000 TONNES MAIZE/MONTH

Product	Per cent Recovery	Production (tons)	Rate/tonne	Sales(Rs)
1.Maize starch	62	620	2200/-	13,64,000.00
2.Maize oil	2.5	25	7000/-	1,75,000.00
3.Maize oil cake	3.5	35	1200/-	42,000.00
4.Maize gluten	10.0	100	1200/-	1,20,000.00
5.Maize bran	12.0	120	500/-	60,000.00
6.Steep concentrate	6.0	60	1000/-	60,000.00
	96.0 (4 per cent process losses)		Total Revenue(sales) =	18,21,000.00

Profit:

On the basis of the above figures for revenue (sales)

and expenses at a production level of 60 per cent level of the proposed installed capacity, the monthly profit will be as under:

Realisation(sales)	= Rs.18,21,000.00
Less expenses	= Rs.17,82,000.00
Gross profit/month	= Rs. 39,000.00
Annual gross profit	= Rs. 4,68,000.00

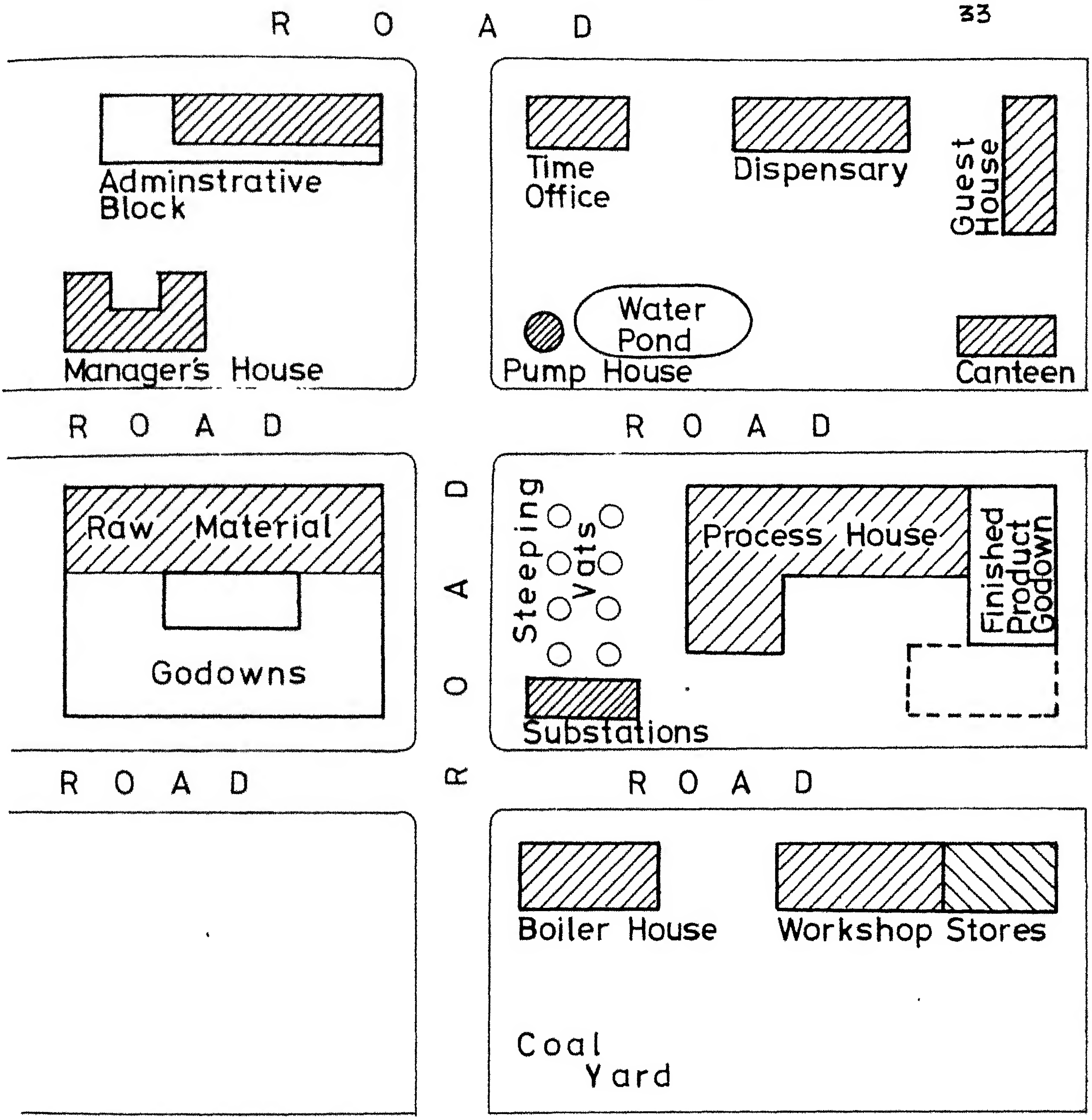


Fig. 6 General Layout For The Maize Starch Factory

CANE SUGAR INDUSTRY

An outline of the development of cane sugar industry in India is discussed briefly in the following pages:

Pre-Independence Period:

A few vacuum pan sugar factories assisted at the beginning of this century. In 1930 there were 30 sugar factories with an annual output of about 1 lakh tonne. By 1947 there were about 137 sugar factories in operation.

Post Independence Period:

In 1950-51 incentives were given for higher sugar production by the Food and Agricultural Ministry. Consequently by the end of the first five year plan i.e. in 1955-56 the number of factories increased to 143 and a record production of 18.92 lakh tonnes was achieved. By 1965-66 the sugar production steadily rose to 33.41 lakh tonnes and the number of units to 200. The Government partially decontrolled the sale of sugar from 1st October 1967. This resulted in an increased sugar output of 37.58 lakh tonnes in 1968-69 from 205 units. The Government decontrolled the sale of sugar with effect from May 25, 1971 because of large surplus stocks of 1969-70. The Government reimposed partial control from 1st July 1972. And this policy continued till July 1978, when Government again decontrolled sugar. Sugar output from 229

units in 1973-74 was 39.48 lakh tonnes.

The estimates by planning commission indicated that about 55 lakh tonnes of sugar was needed for domestic consumption and about 5 lakh tonnes for exports. Therefore sugar production target was fixed at 60 lakh tonnes by the end of fifth five-year plan. Accordingly licences for new sugar factories were issued and the expansion of 32 existing units was allowed. By 1973-74 sugar production reached 47.92 lakh tonnes. It declined to 42.61 lakh tonnes in 1975-76 due to severe draught condition in Tamil Nadu and Andhra Pradesh [7]. During 1976-77 the production increased to 48.40 lakh tonnes [8]. The following year, that is 1977-78 had the record production of 64.7 lakh tonnes.

TABLE 7

GROWTH OF SUGAR FACTORIES AND SUGAR PRODUCTION[10,11,12]

S.No.	Year	No. of Units	Sugar Production (Lakh tonnes)
1	1932	32	10.92
2	1952-53	134	13.18
3	1957-58	158	20.10
4	1962-63	186	21.32
5	1967-68	200	22.49
6	1972-73	229	38.73
7	1976-77	271	48.40
8	1977-78	272	64.72

TABLE 8

DETAILS OF SUGARCANE PRODUCTION AND INDUSTRIES IN MAHARASHTRA[13]

Year	No.of sugar factories	Area 1000 ha. cultivation	Average yield tonnes/ha	Sugar recovery
1971-72	42	182	63.15	11.08
1972-73	47	146	67.13	10.68
1973-74	45	165	78.44	10.69
1974-75	52	185	92.85	11.17
1975-76	55	217	88.33	11.15

IMPORTANCE OF SUGAR INDUSTRY IN NATIONAL ECONOMY:

Sugar is the second largest industry after textiles. There are about 272 sugar factories in operation, all over the country. During 1975-76 the total investment measured in terms of aggregate assets in the industry was of the order of Rs.750 crores. Its product value exclusive of excise duty was Rs.920 crores. About 25 million cultivation were engaged in growing sugarcane to whom the industry paid Rs.575 crores during 1975-76. The industry provided direct employment to 2.6 lakh persons. The annual wages bill of the industry was over Rs.90 crores. The fiscal contribution of the industry to the exchequer of the Central and State Governments in the form of excise duty and cane less was about Rs.300 crores. The industry earned a foreign exchange worth Rs.475 crores

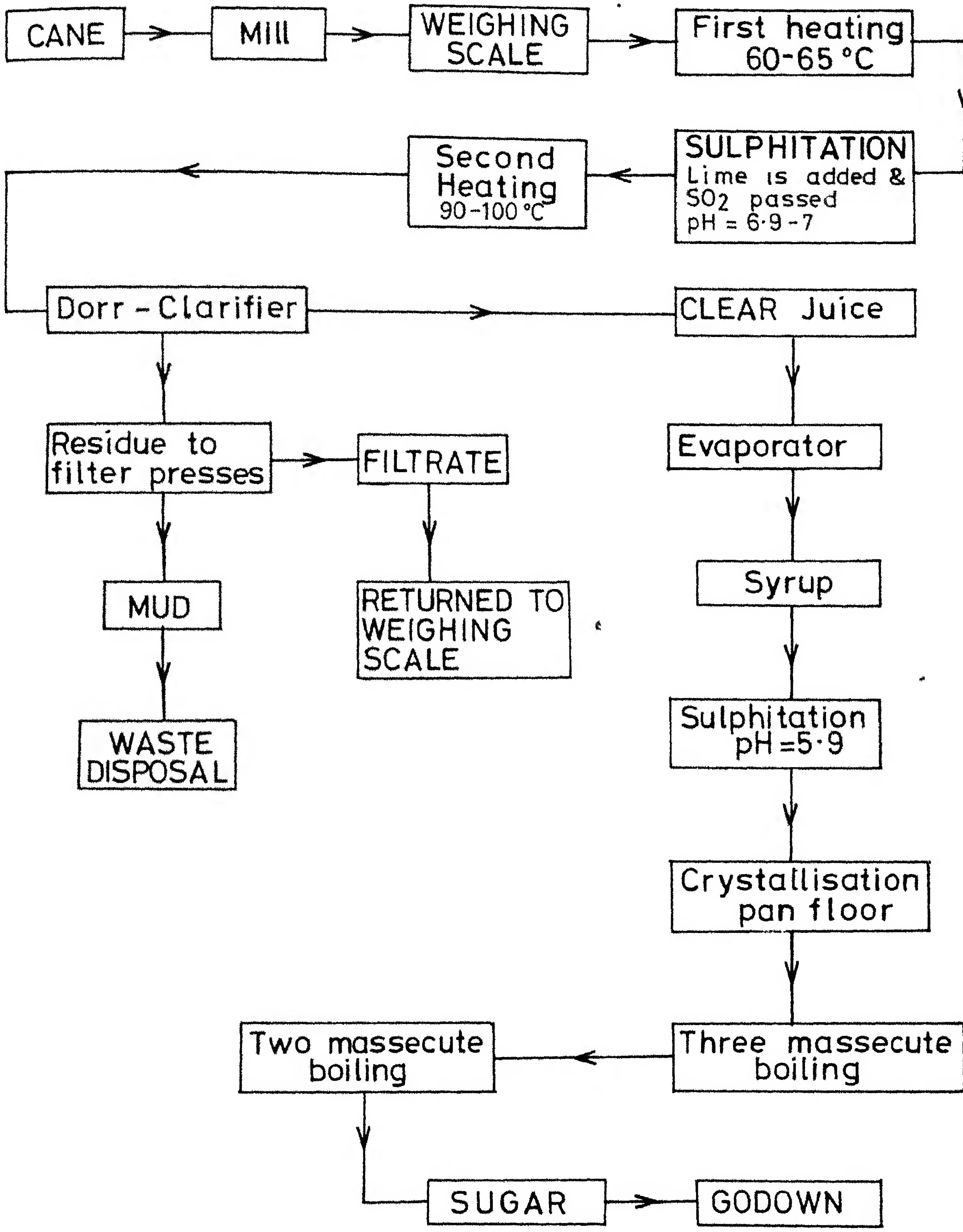


Fig. 7 General Outline Process For Cane Sugar Manufacture

including a rupee profit of Rs.155 crores in 1975. The quantity of sugar exported during 1976 was 8.43 lakh tonnes and the industry earned a foreign exchange worth Rs.268.58 crores [9].

The foregoing discussion would indicate the importance of sugar industry to the nation in terms of its role in domestic production, consumption, employment potential and for foreign exchange earnings. Infact the interaction between grower and the industry is never so complete as in sugar industry.

MANUFACTURING PROCESS FOR CANE SUGAR:

Cane stalks are shredded in crushers and then squeezed through a series of roller mills containing groved walls. Weak juice and make-up water is sprayed as extractant fluid before squeezing to optimize juice yield at 95-96 per cent.

The juice is treated with lime to precipitate colloids. SO_2 is next bubbled through until the pH is 7 to 7.1. This procedure provides maximum floculation of impurities. The SO_2 also acts as a bleaching agent. The juice is next heated to 90-100°C and sent to Dorr-classifier. Clean juice from the classifier flows to evaporator.

The clarified juice is concentrated from 15-20 per cent sugar content to about 60 per cent sugar content in a quadruple effect evaporator. The crystallization is carried out in a vacuum pan unit.

The mixture of crystals and syrup, called massecuite is separated in high speed basket centrifugal. The syrup is

reconcentrated and cooled successively to obtain one or more crops of crystals. The final mother liquor is known as molasses. It is useful byproduct.

The extract expelled from the last mill is known as bagasse. It is the principal fuel for raising steam. Excess bagasse may be used for paper manufacture and for its conversion to several industrial chemicals and products.

Chemicals used in sugar factory:

(a) lime (2 per cent) (b) Sulphur (1 per cent)

(c) triple super phosphate mix juice (0.03 per cent)

(d) NaOH (3 per cent) (e) Formalin (0.1 per cent.)

<u>Expenditure on Chemicals and Packing Materials in a 2000 Tonnes Crushing/day Capacity Sugar Factory</u>

Item	Cost in Rs. (Lakh)/ season
1. Sulphur	0.59
2. Lime and lime stone	17.75
3. Filter cloth	4.00
4. Hassien cloth	0.85
5. Caustic soda	0.17
6. Super phosphate/Phosphoric acid	0.70
7. Chemicals and Lab. Stores	0.40
8. Other chemicals used in process	0.14
9. Packing Material	18.58
Total Expenditure:	43.13

GENERAL STATEMENT OF PLANT CAPACITIES:

(a) Capacity: The consideration of plant capacity is influenced by the minimum economic size of plant and by the demand for the products. From such a consideration and experience of existing units a sugar plant should have a capacity of 2000-3000 T.C.D. although capacity of the existing sugar factories vary from 1250-5000 TCD.

(b) Space Requirement: A plot of about 50-70 acres is adequate to erect a sugar factory considering any future expansion or modernisation.

(c) Power Requirement: On an average the power consumed by a sugar factory in India is in the range of 32-35 H.P. per ton per crushing hour. It is generated in the plant.

(d) Coal/Fuel Requirement: For a daily crushing capacity of about 2000 TCD steam required is about 40 tonnes/hour. Boiler capacity is usually around 30-40 tonnes of steam/hour. Adequate space for storing fuel is provided. Usually a set of 2 or 3 boiler is installed.

(e) Water Requirement: Water needed by a sugar factory is mostly used in producing steam as process water for cooling purposes. In practice the requirement of water is about 12-20 lakh litres per day depending on whether the size of sugar factory is 2500 or 5000 Tonnes per day.

STAGEWISE LIST OF EQUIPMENT WITH SPECIFICATION AND COST:

The following list of equipment is based on guidelines as indicated in the literature [14]. The specifications are broad, but considered adequate for a preliminary project design.

TABLE 9

Stage of Process	Description of Machine	Cost, Rs
1. Cane Receiving and conveying	(a) Weigh bridges	8,00,000.00
	(b) Conveyers	10,00,000.00
	(c) Cranes and cabin	10,00,000.00
	(d) Loader (e) Shredder	10,00,000.00
2. Milling	Tandem (6-rollers) Screens Crushers	30,00,000.00
3. Sulphitation (carbonation clarification unit)	Tanks and Auxiliaries preheaters etc.	30,00,000.00
4. Evaporations and auxiliary systems	Quadruple set	35,00,000.00
5. Crystallizers	One set	15,00,000.00
6. Centrifuges	One set	10,00,000.00
7. Process Tanks		5,00,000.00
8. Conveyors and elevators in bagging section		5,00,000.00
9. Pumps, Piping and other fittings		25,00,000.00

10.	Boilers	Spreader stroker, Skoda or Horse shoe type	1,00,00,000.00
11.	Electrical equipment turbine and power station		1,50,00,000.00
12.	Molasses stores and auxiliaries		15,00,000.00
13.	Building and other structures		45,00,000.00
14.	Land and side development		20,00,000.00
15.	Maintenance shop		10,00,000.00
16.	Office equipment		2,50,000.00
17.	Mis. costs(dryers etc.)		20,00,000.00
18.	Erection and other engineering services		25,00,000.00
	Margin money for working capital		,65,00,000.00
			6,50,00,000.00

COST OF MANUFACTURE:

It comprises of all the expenses incurred in running the factory and includes inter st on borrowed capital, expenses on sales, depreciation on plant and machinery and insurance on total block.

The following estimates are based on actual working data for the year 1976-77 obtained from a sugar mill with a crushing capacity of 2000 tonnes per day in Maharashtra State.

TABLE 10

MANUFACTURING COST OF SUGAR PER TONNE BASIS [25]

Expnediturc	Rs.
1. Raw material i.e. cane	1417.20
2. Manufacturing expenses (including salary and wages)	78.90
3. Repairs and Maintenance	126.80
4. Power and fuel	15.60
5. Overheads and selling	75.50
6. Cost of chemicals and packing material	89.90
7. Depreciation	56.40
8. Taxes (cane cess, commission etc.)	36.50
9. Excise duty	284.50
Total manufacturing cost per tonne of sugar	Rs.2181.30*

Overall sugar production for working season of 200 days = 40,000 Tonnes

Hence the manufacturing cost = 40,000 x 2181.30
= 8,72,52,000 Rs.

Selling price of Sugar = 2200 Rs/Tonne

Sales Value = 40,000 x 2200 Rs.
i.e. = 8,80,00,000.00 Rs.

Annual Profit = Rs.7,48,000.00

***Note:** **A recent article by R.K. Rangan[xx] indicated the cost of production as Rs.2180 per tonne which is in close agreement with the data reported above.**

[xx] R.K. Rangan, 'Sugar Price Fall may hit rural prosparity', The Times of India, Bombay 23-1-1979.

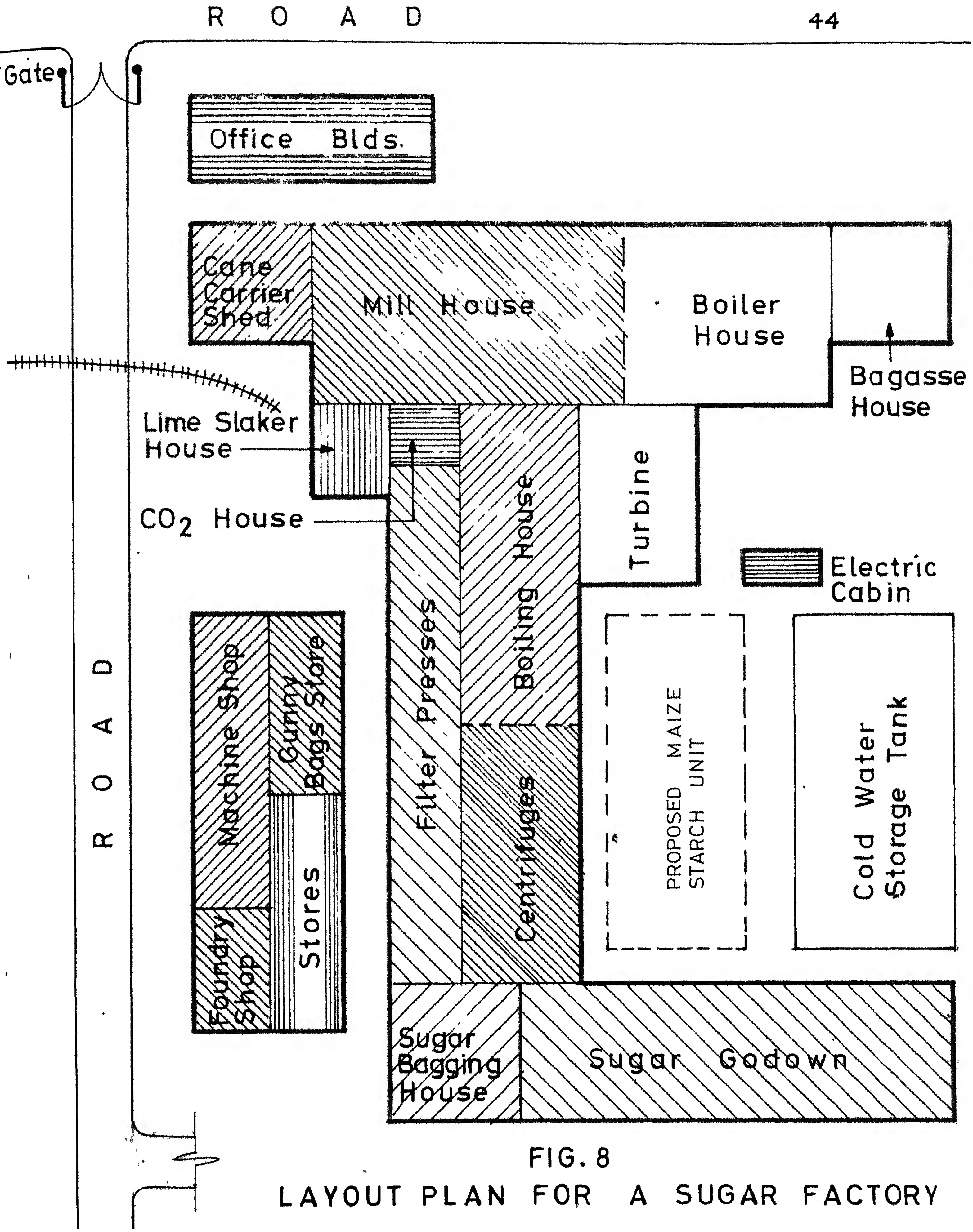


FIG. 8
LAYOUT PLAN FOR A SUGAR FACTORY

COMPANION CROPPING

Some of the ways of increasing the per hectare yield are the techniques of multiple cropping, relay cropping and mixed cropping. Out of the total land of 180 million hectare for cultivation in India, the sugarcane occupies about 25 lakh hectres which is about the 1.4 per cent of the total hecterage available.

Sugarcane takes about 6-8 weeks for germination and another 4-6 weeks for tillering. Evidently it is easily possible to take a cereal crop which would complete its life cycle within about 15 weeks. Recently a number of authors [15-19] have indicated that maize can be conveniently intercropped with sugarcane. The companion cropping of maize has been found helpful in improving fertility of soil and it is extremely profitable. It is also reported that hybrid maize can be intercropped with suru (January), adsali (July) and preseasonal (October) sugarcane as well.

The following observations have been made by different authors [15-20]. On intercropping of maize with sugarcane:

1. No significant difference in germination of cane buds, plant population and yield of cane is observed.

2. The quality of cane juice was improved.

3. The yield of cane decreased marginally by about 2 per cent.
4. Intercropping did not affect the soil properties in general.
5. Additional grain and green fodder are obtained.
6. The overall profit per hectare is increased by about Rs.3000-5000 with intercropping of maize with sugarcane.

From above data, it can be clearly seen that intercropping will help greatly in increasing the maize output and that too without increasing land under the maize crop. It may be possible to enhance maize production by about 20 lakh tonnes. According to a recent survey maize crop grown in India is around 77 lakh tonnes per year.

PERT TECHNIQUE AND PROGRAMMING

The critical path method CPM (29) is a method or a system for planning, scheduling and controlling a project. In CPM steps or operations necessary to complete the project are shown in a graph called network. CPM is one of a family of planning techniques, which includes PERT [21] along many others. It makes use of the fundamental technique of showing the project by means of a diagram of arrows and circles called network or arrow diagram. The chain of operation that determines the total project time is known as critical path and these operations are called critical operations. However, CPM has certain limitations.

Limitations: 1. CPM is not a substitute for thinking or planning.

2. It requires the wholehearted support of management and active participation by people who will direct the work.

The major difference between PERT (Programme Evaluation and Review Technique) and CPM comes in the step of estimating time. PERT is used for projects where there is a great deal of uncertainty about how long any given activity will take. PERT is based on the science of probability. The PERT has been used here to establish time estimates for the implementation of policy measures in a starch unit under consideration.

The optimistic, most probable and pessimistic time estimates (t_o, t_m and t_p) for higher production of maize is put at 0.3, 0.6, and 0.9 years respectively. The basis for these figures is that the maximum time required for maize crop to be ready for harvesting is about 120 days (0.3 years).

t_o, t_m and t_p for producing improved quality of maize (additional production) are put at 0.6, 0.9 and 1.2 years respectively. This is again on the basis of time required for two successive maize crop.

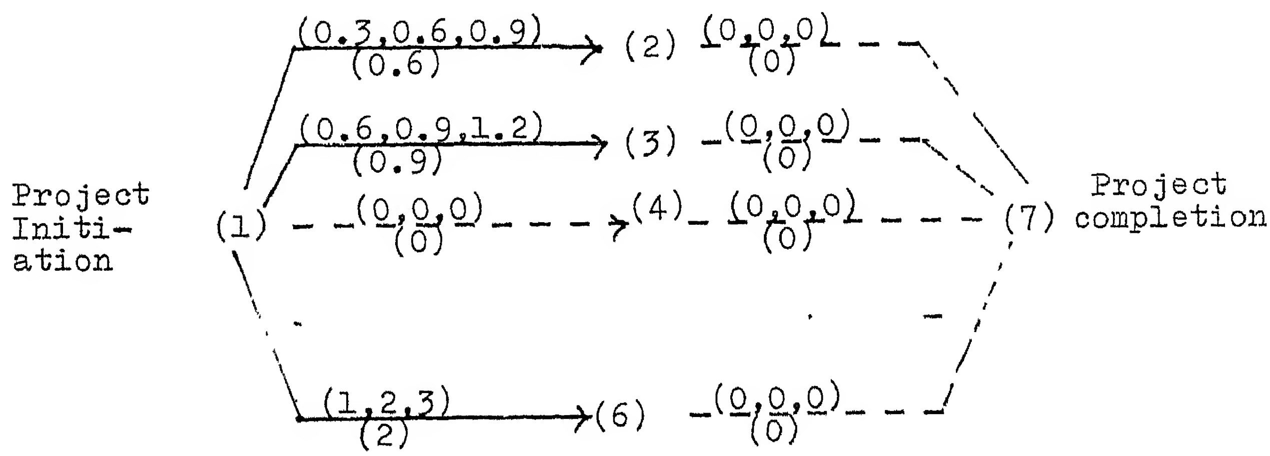
t_o, t_m and t_p for implementation of Government policies are put at (0,0,0) respectively. These measures are implemented by the Government from the very beginning.

t_o, t_m, and t_p for erecting starch unit near an existing sugar factory are 1, 2 and 3 years respectively. These

time estimates are taken on the assumption that the financial requirement and the machinery supplies of the factory are made expeditiously.

With the time estimates determined as above PERT uses a weighted average of the three times t_o, t_m and t_p to find the overall project duration. The average is called the expected time t_e.

$$t_e = \frac{t_o + 4 \times t_m + t_p}{6}$$



$$t_{1-2} = \frac{t_o + 4\ t_m + t_p}{(6)} = \frac{0.3 + 4 \times 0.6 + 0.9}{6} = 0.6$$

$$t_{1-3} = \frac{0.6 + 4 \times 0.9 + 1.2}{6} = 0.9$$

$$t_{1-4} = 0$$

$$t_{1-6} = \frac{1 + 4 \times 2 + 3}{6} = 2.0$$

expected time for completion of project $= \text{Max}((0.6+0), (0.9+0), (0+0), (2+0))$

$= \text{Max}\ (0.6, 0.9, 2)$

Expected time for erecting starch unit $= 2.0$ years

OPTIMIZATION TECHNIQUE(Box 'complex' Method):

This method finds the maximum of multivariable, nonlinear function subject to a nonlinear inequality constraints. For example, the below given function can be maximized where $X_1, \ldots X_n$ are independent variables.

Maximize $F(X_1 , X_2 --- X_N)$

subject to $G_k \leqslant X_k \leqslant H_k$ $K=1,---M$, ; where H_k and G_k are upper and lower constraints.

This method is a sequential search technique. The procedure tends to find the global maximum due to the fact that the initial set of points are randomly scattered throughout the feasible region. The algorithm proceeds as follows:

1. An original complex of $K \geqslant N+1$ points is generated consisting of a feasible starting point and K-1 additional points generated from random numbers and constraints for each of the independent variables: such as

$$X_{i,j} = G_i + r_{i,j} (H_i - G_i)$$

$$i = 1,2 \ldots N, \quad ; \quad j = 1,2, \ldots K-1$$

$r_{i,j}$ are random numbers between 0 and 1

2. The selected point must satisfy both the explicit and implicit constraints. If at any time the explicit constraints are violated, the point is moved a small distance δ inside the violated limit. If an implicit constraint is violated, the point is moved one half of the distance to the centroid of the remaining points.

$$X_{i,j}\ (new) = (X_{i,j(old)} + \bar{X}_{i,c})/2 \qquad i = 1,2\ldots N$$

where $$\bar{X}_{i,c} = \frac{1}{K-1}\left[\sum_{j=1}^{K} X_{i,j} - X_{i,j(old)}\right] \qquad i=1,2,\ldots N$$

The process is repeated as necessary until all the implicit constraints are satisfied.

3. The objective function is evaluated at each point. The point having the lowest function value is replaced by a point which is located at a distance α times as far from the centroid of the remaining points as the distance of the rejected point on the line joining the rejected point and the centroid.

$$X_{i,j(new)} = \alpha\,(\bar{X}_{i,c} - X_{i,j(old)}) + \bar{X}_{i,c}$$

$$i = 1,2,\ldots.N \qquad \alpha = 1.3$$

4. If a point repeats in giving the lowest function value on consecutive trials, it is moved one half the distance to the centroid of the remaining points.

5. The new point is checked against the constraints and is adjusted as before if the constraints are violated.

6. Convergence is assumed when the objective function values at each point are within β units and γ consecutive iterations. However, this method has certain limitations.

<u>Limitations:</u> 1. The method becomes inefficient rapidly as the number of variables increases.

2. It cannot be used to solve problems having equality constraints.

3. The method requires an initial point X_1 that is feasible.

It has been noted from the published data on companion cropping that its application will reduce the cost of maize substantially. This in turn will reduce the cost of starch. But unless we get all the maize required for starch production from companion cropping technique it is difficult to formulate profit function. Therefore computations are made by varying different parameters, such as cost of maize, steam power etc. the results obtained have been given in the tabular form in the appendix (e). An attempt has been made to maximize the profit function also.

RESULTS AND DISCUSSIONS

INTERCROPPING OF MAIZE WITH SUGARCANE:

Intercropping of maize with sugarcane has been studied by several authors (15-19). One typical observation is given below:

TABLE 11

Intercropping of maize with sugarcane.

Year	1968-69	69-70	70-71	Avrage
Production of maize MT/Hec.	4.16	3.66	2.66	3.5
Production of Sugarcane MT/Hec.	143.20	171.66	168.78	161.12

The average production of maize MT/Hec.

$$= \frac{4.16 + 3.66 + 2.66}{3}$$
$$= 3.5.$$

The additional expenditure for fertilizers and water when intercropping is practiced is found to be marginal. Thus the maize crop is obtained as a bonus crop. At an average price of Rs. 900 per tonne of maize this additional maize production would yield a profit of Rs. 3400 per ~~ton~~ hec. It is likely that the average maize production from a companion cropping with sugarcane can be increased further to provide larger economic benefits.

It may be safe to assume that intercropping practice may lead to at least a 10 percent reduction in maizw cost. That is if the market price of maize is Rs. 1000/ per tonne, it will be available at Rs. 900 per tonne by inter-cropping. This will result in the reduction of the cost of manufacture of stareh and by products substantially.

STARCH & SUGAR AS COMBINED UNIT:

Expenditure on Utilities: (Variable parameter costs)

(a) Cost of power: From literature and exprience of existing units, it is known that power requirement is as follows.

A power consumption of 20 H.P. is required for processing one tonne of maize. That is,

1 H.P. hour = 0.7455 Kw. hr ;

Power comsumption / tonne of maize = 20 x 0. 7455 = 15 Kwh

At power tariff = 0.25 Rs/Kwh,

power bill = 15 x 24 x 0.25 = Rs.90.00

(b) Cost of fuel: Fuel is consumed in raising steam and for processing of maize. When coal is used as fuel the expenditure on raising 1 ton of steam amounts to about Rs. 40. One tonne of maize requires 2 times of steam.

Therefore expenditure on fuel for processing 1 ton of maize = 2 x 40 = Rs.80.

(c) Cost of Water: Water requirement has been found to vary between 3 - 5 m^3 water/ tonne of maize processing. An average figure of 4 m^3 water/ tonne of maize processing may be assumed.

At water charges = 0.60 Rs/K.litre,

The expenditure = $0.60 \times \frac{4000}{1000}$ = Rs. 2.4 ≃ 2.5 .

The total expenditure (Utilities) = (a)+(b)+(c) = 90 + 80 +2.5 = Rs.172.5

The effect of parameters of fixed costs such as the cost of labour and supervision, depreciation on plant & machinery, repairs & maintenance etc., is discussed in the table below.

TABLE 12

MONTHLY FIXED COST EXPENDITURE

ITEM		EXPENDITURE (in Rs.)
1. Sulphur		5, 000
2. Wages (labour & Supervision)		70, 000
3. Depreciation	(a)	1,25, 000
	(b)	20, 000
4. Packing Cost		1,00, 000
5. Repairs & maintenance		20, 000
6. Insurance on total block		10, 000
7. Interest on borrowed capital		1,75,000
8. Administration & selling expenses		85, 000
		6,10,000

SAVINGS ON FIXED COST FOR A COMBINEDUNIT

It may be noted that when the starch unit is combined with an existing sugar unit, a saving on the expenses on the itmms (2) & (8) of Table No. 12 can be realised.

i.e.	labour & supervision	= 70,000
	administration & selling	= 85,000
		Rs.1,55,000

In other words total fixed cost expenditure per month for a combined unit would be Rs. 4,55,000 as compared to Rs. 6,10,000 in case of an independent starch unit.

OVER ALL SAVINGS FOR A COMBINED UNIT:

Table 13 gives the profitability data for an independent starch unit at different production level.

Table 14 gives the profitability data for a combined unit at different production level.

It may be observed from column one of tables 13,14 that a profit of Rs. 1,94,000/ month can be realised from a combined unit at a crushing rate of 1000 tonnes of maize/ month as against a meagre profit of Rs. 39,000/ month from an independently operating starch unit. This is obtained when maize is not intercropped. The overall profit is found to increase with increase in capacity.

Table 13 An independent starch unit with maize price at Rs.1000/ per ton.
Capacity maize crushed per month in M.T.

ITEM	Capacity tonnes per month					
	1000	1200	1500	1800	2100	2400
Income	18,21,000	21,85,[illegible]	27,71,500	32,77,800	38,24,100	43,70,400
Expenditure	6,10,000	6,10,000	6,10,000	6,10,000	6,10,000	6,10,000
Maize Cost	10,00,000	12,00,000	15,00,000	18,00,000	21,00,000	24,00,000
Power, fuel etc.	1,72,000	2,06,400	2,58,000	3,09,600	3,61,200	4,12,800
Total Exp.	17,82,000	20,16,400	23,68,000	27,19,600	30,71,200	34,22,800
Profit	39,000	1,68,800	3,53,500	5,58,200	7,52,900	9,47,600

Table 14 Starch plant attached to a Sugar Unit with maize price = Rs. 1000/- per ton.

Item	Capacity tonnes per month					
	1000	1200	1500	1800	2100	2400
Income	18,21,000	21,85,800	27,71,500	32,77,800	38,24,100	43,70,400
Expenditure	4,55,000	4,55,000	4,55,000	4,55,000	4,55,000	4,55,000
Maize Cost	10,00,000	12,00,000	15,00,000	18,00,000	21,00,000	24,00,000
Power,fuel etc.	1,72,000	2,65,400	2,58,000	3,09,600	3,61,200	4,12,800
Total Exp.	16,27,000	18,61,000	22,13,400	25,64,6[illegible]	29,26,200	32,61,800
Profit	1,94,000	3, 23,800	5,18,500	7,13,200	9,07,900	11,02,600

Table 15 shows profitability data from an independently run maize starch unit at different values of typical parameters such as the fuel cost and when maize is intercropped.

Table 16 shows profitability data from an independently run maize starch unit at different values of typical parameters such as the fuel cost and when maize is not intercropped.

It may be noted from Tables 15 and Table 16 that intercropping would lead to substantial increase in profits.

Tables 17 and Table 18 show profitability data from combined unit with and without maize obtained from intercropping. The inprovement in profitability is attractive and it is the highest when maize in intercropped and the starch unit is combined with a sugar factory.

PROFITABILITY OPTIMIZATION OF A COMBINED UNIT :

Box's complex have been used in the present work to establish optimum protitability of a combined starch -cum-sugar unit.

The terms used in optimising the above said unit are defined as given below.

TABLE 15 PROFIT/DAY ON A MAIZE STARCH UNIT (MAIZE IS INTERCROPPED)

Maize cost = Rs. 900/ tonne
Monthly expenditure = 6,10,000 Rs.
Power cost = Rs.90/ per tonne

Various Fuel Values	Rs. 80 Profit	Rs. 85 Profit	Rs. 90 Profit
Tonnage/day			
40	9710	9510	9310
50	15,220	14,970	14,720
60	22,710	22,410	22,110
70	30,240	29,890	29540
80	37,770	37,370	36,970

TABLE 16 PROFIT/DAY ON A MAIZE STARCH UNIT (MAIZE IS NOT INTERCROPPED)

Maize cost = Rs. 1000/ tonne
Monthly expenditure = 6,10,000 Rs.
Power Cost =Rs.90/ tonne

Various fuel values/ tonne	Rs.80 Profit	Rs.85 Profit	Rs. 90 Profit
Tonnage of maize crushed/day			
40	5, 708	5, 570	5, 540
50	12, 220	11, 970	11, 720
60	18, 732	18, 430	18,750
70	25, 242	24, 890	24, 542
80	31, 752	31,355	30,952

TABLE 17: PROFIT/DAY ON A MAIZE STARCH UNIT COMBINED WITH A SUGAR FACTORY

Maize cost = 1000 Rs./tonne
Monthly expenditure = 4,55,000
Power cost Rs '90/tonne

Various fuel values/tonne	Rs.80 Profit	Rs.85 Profit	Rs.90 Profit
Maize tonnage/day	10,876	10,676	10,476
40	10,876	10,676	10,476
50	17,386	17,136	16,886
60	23,896	23,596	23,296
70	30,406	30,056	29,706
80	36,916	36,576	36,116

TABLE 18: PROFIT/DAY ON A MAIZE STARCH UNIT COMBINED WITH A SUGAR FACTORY

Maize cost = Rs.900/tonne
Monthly expenditure = 4,55,000
Power cost = Rs.'90/tonne

Various fuel values	Rs.80 Profit	Rs.85 Profit	Rs.90 Profit
Maize tonnage/day			
40	14,476	14,276	14,076
50	21,886	21,636	21,386
60	28,296	28,996	28,696
70	36,706	36,356	36,006
80	43,116	43,716	43,316

PROFIT FUNCTION = OBJECTIVE FUNCTION = F (I) = F1 + F2.

F1 = PROFIT FUNCTION (SUGAR UNIT)

F2 = PROFIT FUNCTION (STARCH UNIT)

F1 = PFT1* X (I,3) * X (I,1) *X(I,5)
+ X (I,3) * 0.8 * X (I,5)

F2 = PFT2 * X (I,4)*X (I,6).

The calculations are made assuming that

1. Sugar recovery % of cane = 10%
2. Ist grade molasses rate = Rs.40/. Tonne.
3. Molasses % of cane = 2%

X(I,1) = Sugar recovery; X (I,4) = Tonnes of maize per day

X(I,2) = Ist grade molasses in tonnes; X (I,5) = No of days of operation (Sugar Unit)

X(I,3) = Sugar Plant TCD Capacity ; X (I,6) = No of days of operation (starch unit)

The various staps which lead to the optimum solution are given below.

From the values obtained from the optimization program, it is found that when a maize starch unit of 1500 MT/ month is combined with a sugar unit of 2500 TCD capacity, the maize starch unit should be operated for 200 days and sugar unit for 160 days respectively to obtain maximum profits.

PFT1 = 20,0; PFT 2 = 270.0

ITERATION NO 1 COORDINATES OF CORRECTED POINT

X (2,1) =.200000 E + 03; X (2,2) = . 116920 E +04;
X (2,3) = .Ø160000 E + 03; X(2,4) = . 163217 E +03;

VALUES OF THE FUNCTION:

F(1) = .795937 E +08; F(2) =0.521650 E +08; F (3) = .000000 E+00;
F (4)= .464828 E +08; F(5) = .484272 E +08;

ITERATION NO 20: CORDINATES OF CORRECTED POINT

X (3,1) = .244552 E +03; X (3,2) = .149999 E+04;
X(3,3) = .161531 E +03; X (3,4) = .197564 E+03;

VALUES OF THE FUNCTION:

F(1) = .803022 E +08; F(2) = .804792 E +08; F (3) = .806050 E+08;
F (4) = .801299 E +08; F(5) = .801158 E +08;

ITERATION NO 42: COORDINATS OF CORRECTED POINT

X(2,1) = .250000 E +03; X(2,2) = .150000 E +04;
X(2,3) = .160000 E +03; X(2,4) = .200000 E +03;

VALUES OF THE FUNCTION:

F(1) = .815997 E + 08; F (2) = .815998 E + 08; F(3) = .815997 E +08;
F(4) = .815997 E +08; F (5) = .815997 E + 08;

FINAL X VALUES:

X (1) = .2499958 E + 03; X (2) = .14999984 E + 04;
X (3) = .160000 E +03; X (4) = .19999968 E + 03;

PROFITABILITY CHARTS:

Fig. 9 shows the profitability chart for a maize starch unit . Profits of a starch unit are found to increase linearly with capacity. It is but natural because starch manufacture is a completely bottle up process wherein wastage is minimum and almost every component produced is utilized and has a ready market.

It may further be noted from fig. 9 that the intercopping of maize is a highly profitable proposition. It may be noted that the profits increase in the following order.

maize starch unit (independent)	<	maize starch unit Operated with Sugar Unit	<	maize intercropped & starch unit joined with sugar factory

Fig. 10 shows the profitability of a sugar unit . It shows that by merely increasing the plant capacity does not lead to higher profits (as it is in the case for the maize starch unit). This is because of the fact that as the capacity of the plant increases about 2200 TCD the following factors affect the performance adversely.

1. increased overhead charges and maintenance
2. inadequate supply of sugarcane meaning thereby lower capacity utilization of installed capacity.
3. higher cost of raw material.

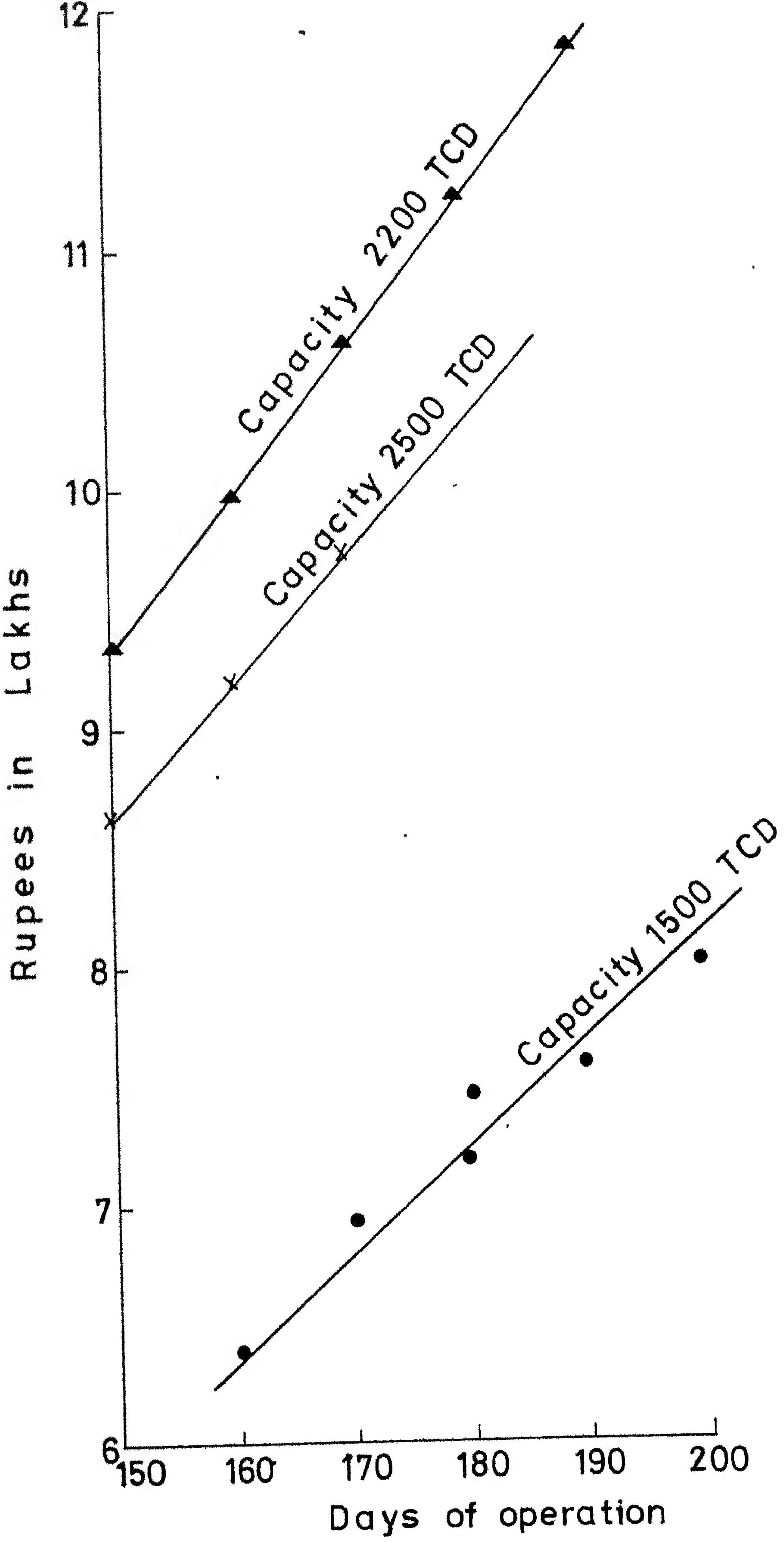


Fig. 10 Profitability (Sugar Unit)

Of the three reasons mentioned above, second reason is the major cause for lower profits. Smaller units have the advantage of regular supply of sugarcane. This trend may be noted from the data given in appendix C

PLANT LAYOUT:

A general plan for a sugar unit is shown in Fig 8. It is found technically feasible to errect a starch manufacturing unit along with the sugar unit as indicated by the dotted lines. As discussed elsewhere starch manufacturing unit is a compact unit and some of its important equipments are available in a sugar factory itself.

Since the parameters like cost of piping, steam carrying cost, location of individual equipment do not affect much the erection of a starch unit near an existing a sugar factory, it is not considered desirable to optimize and compute results with respect to these parameters. If necessary simultaneous equations could be written and solved using programming.

CONCLUSIONS AND SUGGESTIONS

The proposal of a combined maize starch-cum-sugar unit is found feasible and profitable. The intercropping of maize with cane and its subsequent processing in a combined unit would lead to substantial increase in overall profits. The implementation of this proposal may be successfully utilized in solving the problem of sick sugar industries, that is, the sugar industries which are currently in - ed. Presently the incidence of sickness is spread all over the three sectors viz., private, co-operative and public. In Maharashtra, out of more than 40 units appeared in the list only a year ago in spite of the fact that these units are working with modern machinery and equipments (26). A starch unit run along with a sugar unit will certainly help in decreasing the overall losses considerably. It has however, been assumed that additional starch thus produced would be easily sold. It has been reported by the maize starch manufacturers that adequate amounts of good quality maize (hybrid) are not readily available. Some sort of an incentive scheme to develop hybrid quality maize may be undertaken.

It is found that the production of maize through companion cropping would result in economic gains to the farmer. A suitable scheme for promoting intercropping, may be to provide adequate incentives by way of advances

to the farmers by the factories with promise to purchase maize at reasonable prices. The author had visited the Bazpur Cooperative Sugar Factory. He was impressed by their plans to develop better varieties of sugar cane. One of the models for development of Contract Farming and activities around Maize processing, factories which would probably gain rapid official appraisal from State Governments, local authorities and banks, could be similar to the project for comprehensive development of the command area of the Bazpur Cooperative Sugar Factory in the Terai belt of Naini Tal District in Uttar Pradesh submitted recently by the Agricultural Finance Corporation to the UP Government This consists of a set of programmes for comprehensive development within a 16 km. radius of the factory covering a full spectrum of agricultural and agro-based activities, and covers soil and water conservation and irrigation development. This will insure availability of quality maize at reasonable prices and should result in lower costs of production.

REFERENCES

1. Gehlawat, J.K. 'The Treasure in Maize' Indian Chemical Jl. 1971, 6(1), 159.
2. Gehlawat, J.K.,'Starch - A Potential Source of Organic Chemicals', Chemical Weekly Nov. 7, 1972.
3. Gehlawat, J.K.,'Starch and Related Products in India', Indian Chemical Jl. 1967, 1(8), 27.
4. Gehlawat, J.K and Pandya, S.B., 'Pyrodextrinisation of Starch', Chemical Industry Developments, March 1975.
5. Gehlawat, J.K. and Pandya, S.B. Chemical Industry Development, October 1973.
6. Gehlawat, J.K., 'Tapping the Treasure in Maize' Paper presented at Ist Asian Pacific Confederation of Chemical Engineers held at D'Jakarta on Nov. 21-22, 1978.
7. Indian Sugar Year-Book, 1975-76 ISMA, New Delhi 1979 p.1-6,48.
8. Indian sugar Vol.27, no.10, January 1978, XVI.
9. 'Importance to National Economy' Indian Sugar Book 1975-76, p.6-8.
10. Indian Sugar Manual 1963-64, STAI, Kanpur, Table No.105, p.304.
11. Sugar Year Book 1974-75 ISMA, Delhi, Table No.25, p.60 and Table No.30 p. 68).
12. 'Note on Sugar Industry' S.L. Jain Hindustan Times of 30th December 1978.

13. Indian Sugar Journal, Feb. 1977, p.763.

14. S. Mukherjee, 'Construction and Installation of a New Sugar Plant' Cooperative Sugar, Aug. 1977,vol.8 no.2.

15. Ashraf, Pai and Zaman, Maharashtra Sugar Vol.3, No.11, September 1978, p.39.

16. J.S. Patil et al., Maharashtra Sugar Vol.3,no.7, July 1978, p.41.

17. S.H.Gawhane, R.S. Patil 'Indian Sugar' vol.26, no.7,Oct. 1976, p.43.

18. Ibid DSTA Convection, 1976.

19. R.S. Patil, Mullick and Randive, DSTA Convention 1976.

20. J.Horowitz, 'Critical Path Scheduling', The Ronald Press Company, New York.

21. J.M.Weist and T.F. K. Levy 'A Management Guide to PERT/CPM P.H., New Delhi.

22. P.H. Hugot 'Sugar Engineering'.

23. L.A.Tromp 'Machinery and Equipment of Cane Sugar Factory'.

24. V.C. Malshe, 'Alcohol is not for Drinking only', Science To-day' August 1978.

25. Private communication.

APPENDIX A

SHREE WARNA SAHAKARI SAKHAR KARKHANA

Sub: Techno-economic study of the proposal for a sugar mill-cum-starch complex.

We have undertaken a research project to study the techno-economic feasibility of the above proposal. You are among the leading and well established cane sugar manufaturers. We shall appreciate your cooperation in providing relevant commercial and plant operational data as per the following questionare:

Questionare: (Commercial & Operational data of the sugar mill)

A.

1.	The installed capacity	2000	tons/day
2.	Average crushing	~~2000~~	tons/day
3.	Normal crushing season (Nov. to April)	180	days/year (average)
4.	Average annual production	40000	tons/year
5.	Type of sugar-cane used (Adsali, Suru or pre-seasonal)	Suru	
6.	Effect of sugar cane type on sugar quality	Nil	
7.	Average purchase price of sugar cane (as received at the mills including handling & transport charges).	175	Rs./ton

8. Average sugar recovery of the month/season 12.00 %

9. To enable us to compute the production cost, kindly suppy the following information.

a. Average power bill per month Rs. 0.25 lakhs

b. Average fuel bill per month Rs. 0.35

c. Average [illegible]
supervising & plant staff 2,21,470

d. Average monthly salary bill of the office and administrative staff Rs. 1,63,365

e. Average monthly cost of raw materials (Sugar cane & other supplies packing materials etc.) Rs. 47.00 lak

f. Average monthly cost of sugar cane collection Rs. 6.96

g. Average monthly cost of maintenance and repairs Rs. 4.70

h. Average monthly [illegible] and administrative [illegible] not included [illegible] Rs. 2.80

i. Average monthly [illegible] quality [illegible] & not included [illegible] in (e) Rs. —

j. Average monthly expenditure on R & D Rs.

k. Misc. average monthly expences on labour welfare activities Rs. 0.22

Note: The above information should be a reasonable estimate of the avera[ge] monthly expences during the crushing season.

l. An estimate of the total expenditure on the salaries of permanent staff, layoff wages, welfare activities, selling & administrative expences during the off-season Rs. 12,00000

The following data will prove helpful to calculate the contribution of th[e] other factors to the total cost of the sugar manufactured.

i.	Cost of cane ratoons, per ton basis	Rs. — P.S. 0.82
ii.	purchase commission, if any, per ton basis	—
iii.	loading and unloading charges, per ton basis	21.87
iv.	Transport charges, per ton basis	

v. ~~Field expenses on cane~~ collection/inspection, per ton basis [illegible]

vi. Average annual expenses on research and development [illegible]

vii. Average annual taxes (direct & indirect) [illegible]

1. [illegible] annual production of sugar during last five years:

	Year	Total ~~Average~~ sugar production M.T.	Average recovery
1.	1973-74	20673.500	11.49
2.	1974-75	42669.000	12.65
3.	19[illegible]	41949 000	12.54
4.	1976-77	[illegible]452 300	12.35
5.	1977-78 up to [illegible]/3/78	31[illegible] 000	12.10

2. How much levy sugar has to be released per season or year

During the 1976-77

Levy sugar released — 251430 bags.

3. Major factors which affect sugar-production during the working season

APPENDIX B

PER QUINTAL MANUFACTURING COST OF SUGAR (in Rupees)

Item	Factories 1	2	3	4
1. Price of cane	141.81	161.99	158.70	142.26
2. Manufacturing expenses (i) Power and fuel	1.74	0.34	1.287	0.93
(ii) Packing material and chemicals	5.78	4.02	6.65	5.95
3. Wages and Salaries	4.05	4.185	6.66	10.31
4. Overheads and selling	7.50	10.87	7.688	13.00
5. Repairs and Maintenance	12.68	4.27	2.435	2.352
6. Research and Development	-	0.592	2.642	-
7. Depreciations	5.76	5.000	5.26	8.461
8. Taxes	1.80	-	-	-
9. Excise duty	36.26	38.25	38.25	38.25
	217.57	229.517	229.572	229.62

The above data are obtained from four different sugar factories operating in Maharashtra State.

APPENDIX [illegible]

TABLE : ACTUAL PERFORMANCE DATA OF WORKING SUGAR FACTORIES IN MAHARASHTRA

	No. of days	Money obtained by selling Sugar	Money obtained by selling Molasses	Overall Profit
Capacity = 2200 TCD	150	7,26,000	2,71,200	9,37,200
Sugar recovery per cent cane=11 per cent	160	7,74,400	2,25,280	9,99,680
First grade molasses = 1.6 per cent	170	8,22,800	2,39,360	10,62,160
Profit/tonne sugar = 20 Rs.	180	8,71,200	2,53,440	11,24,640
	190	9,19,600	2,67,520	11,87,120
	200	9,68,000	2,81,600	12,49,600
Capacity = 2500 TCD	150	6,18,750	2,40,000	8,58,750
Sugar recovery per cent of cane = 11 per cent	160	6,60,000	2,56,000	9,16,000
Recovery of malasses = 1.6 per cent	170	7,01,250	2,72,000	9,73,250
Profit = Rs.15/tonne				

APPENDIX D

COMPLEX PROCEDURE OF BOX

```
      DIMENSION X(5,4),R(5,4),F(5),G(4),H(4),XC(4)
      INTEGER GAMMA
      READ 1,N,M,K,ITMAX,IC,IPRINT
    1 FORMAT(8I5)
      READ 2,ALPHA,BETA,GAMMA
    2 FORMAT(2E10.4,I5)
      DELTA=0.0001
      READ 4,(X(1,J),J=1,N)
    4 FORMAT(8E10.4)
      DO 100 II=2,K
      READ 3,(R(II,JJ),JJ=1,N)
    3 FORMAT(8F10.4)
  100 CONTINUE
      PRINT 10
   10 FORMAT(1H1,//,18X,24HCOMPLEX PROCEDURE OF BOX)
      PRINT 18
   18 FORMAT(//,2X,10HPARAMETERS)
      PRINT 11,N,M,K,ITMAX,IC,ALPHA,BETA,GAMMA,DELTA
11        FORMAT(//,2X,4HN = ,I2,3X,4HM = ,I2,3X,4HK = ,I2,2X,8HITMAX =
     1I4,2X,5HIC = ,I2,//,2X,8HALPHA = ,F5.2,5X,7HBETA = ,F10.5,3X,
     28HGAMMA = ,I2,3X,8HDELTA = ,F6.5)
      IF (IPRINT)40,50,40
   40 PRINT 12
   12 FORMAT(//,2X,14HRANDOM NUMBERS)
      DO 200 J=2,K
      PRINT 13, (J,I,R(J,I),I=1,N)
   13  FORMAT(/,4(2X,2HR(,I2,1H ,I2,4H) = ,F6.4,2X))
  200 CONTINUE
   50 CALL CONSX(N,M,K,ITMAX,ALPHA,BETA,GAMMA,DELTA,X,R,F,IT,IEV2,G,H,
     1XC,IPRINT)
      IF(IT-ITMAX) 20,20,30
   20 PRINT 14,F(IEV2)
   14 FORMAT(///,2X,30HFINAL VALUE OF THE FUNCTION = ,E20.8)
      PRINT 15
   15 FORMAT(//,2X,14HFINAL X VALUES)
      DO 300 J=1,N
      PRINT 16,J,X(IEV2,J)
   16 FORMAT(/,2X,2HX(,I2,*)*,3H = ,E20.8)
  300 CONTINUE
      GO TO 999
   30 PRINT 17,ITMAX
   17 FORMAT(///,2X,38H THE NUMBER OF ITERATIONS HAS EXCEEDED,I4,10X,
     118HPROGRAM TERMINATED)
  999 STOP
      END
```

```
      SUBROUTINE CONSX(N,M,K,ITMAX,ALPHA,BETA,GAMMA,DELTA,X,R,F,IT,IEV2,
     1G,H,XC,IPRINT)
      DIMENSION X(5,4),R(5,4),F(5),G(4),H(4),XC(4)
      INTEGER GAMMA
      IT=1
      KODE=0
      IF(M-N)20,20,10
   10 KODE=1
   20 CONTINUE
      DO 40 II=2,K
      DO 30 J=1,N
   30 X(II,J)=0.0
   40 CONTINUE
      DO 65 II=2,K
      DO 50 J=1,N
      I=II
      CALL CONST(N,M,K,X,G,H,I)
      X(II,J)=G(I)+R(II,J)*(H(I)-G(I))
   50 CONTINUE
      K1=II
      CALL CHECK (N,M,K,X,G,H,I,KODE,XC,DELTA,K1)
      IF(II-2) 51,51,55
   51 IF(IPRINT) 52,65,52
   52 PRINT 18
   18 FORMAT(//,2X,30HCOORDINATES OF INITIAL COMPLEX)
      IO=1
      PRINT 19,(IO,J,X(IO,J),J=1,N)
   19 FORMAT(/,3(2X,2HX(,I2,1H ,I2,4H) = ,E13.6))
   55 IF(IPRINT) 56,65,56
   56 PRINT 19,(II,J,X(II,J),J=1,N)
   65 CONTINUE
      K1=K
      DO 70 I=1,K
      CALL FUNC(N,M,K,X,F,I)
   70 CONTINUE
      KOUNT=1
      IA=0
      IF(IPRINT) 72,80,72
   72 PRINT 21
   21 FORMAT(/,2X,22HVALUES OF THE FUNCTION)
      PRINT 22,(J,F(J),J=1,K)
   22 FORMAT(/,3(2X,2HF(,I2,4H) = ,E13.6))
   80 IEV1=1
      DO 100 ICM=2,K
      IF(F(IEV1)-F(ICM)) 100,100,90
```

```
 90 IEV1=ICM
100 CONTINUE
    IEV2=1
    DO 120 ICM=2,K
    IF(F(IEV2)-F(ICM))110,110,120
110 IEV2=ICM
120 CONTINUE
    IF(F(IEV2)-(F(IEV1)+BETA)) 140,130,130
130 KOUNT=1
    GO TO 150
140 KOUNT=KOUNT+1
    IF(KOUNT-GAMMA) 150,240,240
150 CALL CENTR(N,M,K,IEV1,I,XC,X,K1)
    DO 160 JJ=1,N
160 X(IEV1,JJ)=(1.0+ALPHA)*(XC(JJ))-ALPHA*(X(IEV1,JJ))
    I=IEV1
    CALL CHECK(N,M,K,X,G,H,I,KODE,XC,DELTA,K1)
    CALL FUNC(N,M,K,X,F,I)
170 IEV2=1
    DO 190 ICM=2,K
    IF(F(IEV2)-F(ICM)) 190,190,180
180  IEV2=ICM
190  CONTINUE
    IF(IEV2-IEV1) 220,200,220
200  DO 210 JJ=1,N
    X(IEV1,JJ)=(X(IEV1,JJ)+XC(JJ))/2.0
210 CONTINUE
    I=IEV1
    CALL CHECK (N,M,K,X,G,H,I,KODE,XC,DELTA,K1)
    CALL FUNC (N,M,K,X,F,I)
    GO TO 170
220 CONTINUE
    IF(IPRINT) 230,228,230
230  PRINT 23, IT
 23 FORMAT(//,2X,17HITERATION NUMBER ,I5)
    PRINT 24
 24 FORMAT(/,2X,30HCOORDINATES OF CORRECTED POINT)
    PRINT 19,(IEV1,JC,X(IEV1,JC),JC=1,N)
    PRINT 21
    PRINT 22,(I,F(I),I=1,K)
    PRINT 25
 25 FORMAT(/,2X,27HCOORDINATES OF THE CENTROID)
    PRINT 26, (JC,XC(JC),JC=1,N)
 26 FORMAT(/,3(2X,2HX(,I2,6H,C) = ,E14.6,4X))
228 IT=IT+1
```

```
      IF(II-IIMAX)  60,60,240
  240 RETURN
      END
      SUBROUTINE CHECK(N,M,K,X,G,H,I,KODE,XC,DELTA,K1)
      DIMENSION X(5,4),G(4),H(4),XC(4)
   10 KT=0
      CALL CONST (N,M,K,X,G,H,I)
      DO 50 J=1,N
      IF(X(I,J)-G(J))  20,20,30
   20 X(I,J)=G(J)+DELTA
      GO TO 50
   30 IF(H(J)-X(I,J)) 40,40,50
   40 X(I,J)=H(J)-DELTA
   50 CONTINUE
      IF (KODE) 110,110,60
   60 NN=N+1
      DO 100 J=NN,M
      CALL CONST (N,M,K,X,G,H,I)
      IF(X(I,J)-G(J))  80,70,70
   70 IF(H(J)-X(I,J)) 80,100,100
   80 IEV1=I
      KT=1
      CALL CENTR (N,M,K,IEV1,I,XC,X,K1)
      DO 90 JJ=1,N
      X(I,JJ)=(X(I,JJ)+XC(JJ))/2.0
   90 CONTINUE
  100 CONTINUE
      IF(KT) 110,110,10
  110  RETURN
      END
      SUBROUTINE CENTR(N,M,K,IEV1,I,XC,X,K1)
      DIMENSION X(5,4),XC(4)
      DO 20 J=1,N
      XC(J)=0.0
      DO 10 IL=1,K1
   10 XC(J)=XC(J)+X(IL,J)
      RK=K1
   20 XC(J)=(XC(J)-X(IEV1,J))/(RK-1.0)
      RETURN
      END
      SUBROUTINE  FUNC(N,M,K,X,F,I)
      DIMENSION X(5,4),F(5)
C SUGAR FACTORY OPTMZ
      IF(X(I,3).GT.160.0.AND.X(I,4).GT.160) GO TO 10
      F(I)=0.0
```

```
      RETURN
   10  IF(X(I,3)+X(I,4).LE.360.0) GO TC 20
      F(I)=0.0
      RETURN
   20 PFT1=20.0
      IF(X(I,1).LE.220.0) PFT1=15.0
      PFT2=270.0
      F1=PFT1*X(I,1)*X(I,3)
      F2=PFT2*X(I,2)*X(I,4)
      F(I)=F1+F2
      RETURN
      END
      SUBROUTINE CONST(N,M,K,X,G,H,I)
      DIMENSION X(5,4),G(4),H(4)
       G(1)=200.0
      H(1)=250.0
      G(2)=1000.0
      H(2)=1500.0
      G(3)=160.0
      H(3)=200.0
      G(4)=160.0
      H(4)=200.0
      RETURN
      END
    4     4     5 1000     1     1
1.3000E+001.0000E+03       5
0.2500E+031.5000E+030.1650E+030.1950E+03
   .0052    .1820     .1356        .6534
   .4037    .7880      .8764       .8632
   .9306     .5248      .4658      .2378
```

```
      PROGRA'     T  ...                        CC, IIT/K
C  WATFOR  ...       ...
$WATFOR  ...    ...                       10        7/3/79
      DIMENSION  ... (6),POWER(6),FUEL(6),MFG(6),PROFT(6),T(6)
      REAL ...
      REAL ... ,(...(I),I=1,6)
      REAL ... ,(...(I),I=1,6)                                   0,00
      REAL 10,(...(I),I=1,6)
      REAL 10,(MFG(I),I=1,6)
      REAL 10,(FUEL(I),I=1,6)
   10 FORMAT(6F10.2)                                             ,999
      REV=...1.0
      CONST=REV                                                  ,997
      DO 105 LL=1,6
      PRINT 141,MFG(LL)                                          ,997
  141 FORMAT(/,12X,*AT MFG COST*,F7.1)
      DO 200 I=1,6                                               ,993
      PRINT 100
  100 FORMAT(/,1X,120(1H-))                                      ,993
      PRINT 90,MZCST(I)
   90 FORMAT(/,12X,*FOR MAIZE COST*,F7.1)                        ,989
      PRINT 100
      DO 190 J=1,6
      PRINT 110,POWER(J)
  110 FORMAT(/,12X,*AT POWER COST*,F7.1)
      PRINT 120                                                  0,00
  120 FORMAT(/,12X,*VARIOUS FUEL VALUES*)
      PRINT 130,(FUEL(K),K=1,6)
  130 FORMAT(/,5X,*TONNE*,6F12.2)
      PRINT 100
      DO 180 KK=1,6                                              ,999
      DO 170 M=1,6
  170 PROFT(M)=T(KK)*(CONST-MZCST(I)-POWER(J)-FUEL(M))-MFG(LL)   ,997
      PRINT 140,T(KK),(PROFT(L),L=1,6)
  140 FORMAT(/,3X,F6.2,1X,6F12.3)                                ,997
  180 CONTINUE
  190 CONTINUE                                                   ,997
  200 CONTINUE
  105 CONTINUE                                                   ,993
      PRINT 100
      STOP                                                       ,993
       END
COMPILETIME ERRORS:
  0
##
$ENTRY
                                                                 0,00
            AT MFG COST20330,0
```

AT POWER COST 90,0

VARIOUS FUEL VALUES

TONNE	[illegible]	85,00	90,00	95,00	100,00
50,00	[illegible]	16969,999	16720,000	16469,999	16219,999
60,00	[illegible]	24429,999	24129,997	23829,997	23529,997
70,00	[illegible]	31889,999	31539,999	31189,997	30839,997
80,00	[illegible]	39349,997	38949,993	38549,997	38149,993
90,00	[illegible]	46809,997	46359,997	45909,997	45459,993
100,00	[illegible]	54269,989	53769,989	53269,989	52769,989

AT POWER COST 95,0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	16969,999	16720,000	16469,999	16219,999	15969,999
60,00	24429,999	24129,997	23829,997	23529,997	23229,997
70,00	31889,999	31539,999	31189,997	30839,997	30489,997
80,00	39349,997	38949,993	38549,997	38149,993	37749,997
90,00	46809,997	46359,997	45909,997	45459,993	45009,993
100,00	54269,989	53769,989	53269,989	52769,989	52269,993

AT POWER COST 100,0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	16720,000	16469,999	16219,999	15969,999	15720,000
60,00	24129,997	23829,997	23529,997	23229,997	22929,997
70,00	31539,999	31189,997	30839,997	30489,997	30139,999
80,00	38949,993	38549,997	38149,993	37749,997	37349,997
90,00	46359,997	45909,997	45459,993	45009,993	44559,993
100,00	53769,989	53269,989	52769,989	52269,993	51769,989

AT POWER COST [illegible]0,0

VARIOUS FUEL VALUES

TONNE	[illegible]	85,00	90,00	95,00	100,00
50,00	[illegible]	14470,000	14220,000	13969,999	13719,999
60,00	[illegible]	21429,997	21129,997	20829,997	20529,997
70,00	[illegible]	28389,997	28039,999	27689,999	27339,997
80,00	[illegible]	35549,997	34949,997	34549,997	34149,997
90,00	[illegible]	42309,993	41859,993	41409,993	40959,993
100,00	[illegible]	49269,993	48769,993	48269,997	47769,993

AT POWER COST 95.0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	14470,000	14220,000	13969,999	13719,999	13469,999
60,00	21429,997	21129,997	20829,997	20529,997	20229,997
70,00	28389,997	28039,999	27689,999	27339,997	26989,997
80,00	35349,997	34949,997	34549,997	34149,997	33750,001
90,00	42309,993	41859,993	41409,993	40959,993	40509,989
100,00	49269,993	48769,993	48269,997	47769,993	47269,993

AT POWER COST 100.0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	14220,000	13969,999	13719,999	13469,999	13220,000
60,00	21129,997	20829,997	20529,997	20229,997	19929,997
70,00	28039,999	27689,999	27339,997	26989,997	26639,997
80,00	34949,997	34549,997	34149,997	33750,001	33349,999
90,00	41859,993	41409,993	40959,993	40509,989	40059,993
100,00	48769,993	48269,997	47769,993	47269,993	46769,993

AT [illegible] 90,0

[illegible]

TONNE	[illegible]	85,00	90,00	95,00	100,00
50,00	[illegible]	[illegible]	11720,000	11469,999	11219,999
60,00	[illegible]	[illegible]	18129,997	17829,997	17529,997
70,00	[illegible]	[illegible]	24539,997	24189,997	23839,999
80,00	[illegible]	[illegible]	30949,997	30549,999	30149,999
90,00	[illegible]	37809,997	37359,993	36909,993	36459,993
100,00	[illegible]	44269,993	43769,993	43269,997	42769,993

AT POWER COST 95,0

VARICUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	11970,000	11720,000	11469,999	11219,999	10969,999
60,00	18429,999	18129,997	17829,997	17529,997	17229,997
70,00	24889,999	24539,997	24189,997	23839,999	23489,997
80,00	31349,997	30949,997	30549,999	30149,999	29749,999
90,00	37809,997	37359,993	36909,993	36459,993	36009,993
100,00	44269,993	43769,993	43269,997	42769,993	42269,993

AT POWER COST 100,0

VARICUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	11720,000	11469,999	11219,999	10969,999	10720,000
60,00	18129,997	17829,997	17529,997	17229,997	16929,999
70,00	24539,997	24189,997	23839,999	23489,997	23139,999
80,00	30949,997	30549,999	30149,999	29749,999	29349,997
90,00	37359,993	36909,993	36459,993	36009,993	35559,997
100,00	43769,993	43269,997	42769,993	42269,993	41769,993

AT POWER COST 90,0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	7219,999	6969,999	6719,999	6469,999	6219,999
60,00	12729,999	12430,000	12129,999	11829,999	11529,999
70,00	18229,997	17889,999	17539,999	17189,999	16839,997
80,00	23750,001	23349,999	22949,999	22549,999	22149,999
90,00	29259,997	28809,995	28359,995	27909,995	27459,995
100,00	34769,993	34269,993	33769,997	33269,997	32769,995

AT POWER COST 95.0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	6969,999	6719,999	6469,999	6219,999	5969,999
60,00	12430,000	12129,999	11829,999	11529,999	11230,000
70,00	17889,999	17539,999	17189,999	16839,997	16489,997
80,00	23349,999	22949,999	22549,999	22149,999	21749,999
90,00	28809,995	28359,995	27909,995	27459,995	27009,995
100,00	34269,993	33769,997	33269,997	32769,995	32269,995

AT POWER COST 100.0

VARIOUS FUEL VALUES

TONNE	80.00	85,00	90,00	95,00	100,00
50,00	6719,999	6469,999	6219,999	5969,999	5719,999
60,00	12129,999	11829,999	11529,999	11230,000	10930,000
70,00	17539,999	17189,999	16839,997	16489,997	16139,999
80,00	22949,999	22549,999	22149,999	21749,999	21349,997
90,00	28359,995	27909,995	27459,995	27009,995	26559,997
100,00	33769,997	33269,997	32769,995	32269,995	31769,995

```
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

$WATFOR  R K KELKAR    20 FEB           10        7/3/79

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

      PROGRAM    TDC-316                     CC, IIT/K
      DIMENSION MZCST(6),POWER(6),FUEL(6),MFG(6),PROFT(6),T(6)
      REAL MZCST
      READ 10,(T(I),I=1,6)
      READ 10,(MZCST(I),I=1,6)
      READ 10,(POWER(I),I=1,6)
      READ 10,(MFG(I),I=1,6)
      READ 10,(FUEL(I),I=1,6)
   10 FORMAT(6F10.2)
      REV=1821.0
      CONST=REV
      DO 105 LL=1,2
      PRINT 141,MFG(LL)
  141 FORMAT(/,12X,*AT MFG COST*,F/.1)
      DO 200 I=1,6
      PRINT 100
  100 FORMAT(/,1X,120(1H-))
      PRINT 90,MZCST(I)
   90 FORMAT(/,12X,*FOR MAIZE COST*,F/.1)
      PRINT 100
      DO 190 J=1,3
      PRINT 110,POWER(J)
  110 FORMAT(/,12X,*AT POWER COST*,F/.1)
      PRINT 120
  120 FORMAT(/,12X,*VARIOUS FUEL VALUES*)
      PRINT 130,(FUEL(K),K=1,6)
  130 FORMAT(/,5X,*TONNE*,6F12.2)
      PRINT 100
      DO 180 KK=1,6
      DO 170 M=1,6
  170 PROFT(M)=T(KK)*(CONST-MZCST(I)-POWER(J)-FUEL(M))-MFG(LL)
      PRINT 140,T(KK),(PROFT(L),L=1,6)
  140 FORMAT(/,3X,F6.2,1X,6F12.3)
  180 CONTINUE
  190 CONTINUE
  200 CONTINUE
  105 CONTINUE
      PRINT 100
      STOP
       END
COMPILETIME ERRORS:NIL !
##
$ENTRY

           AT MFG.COST15164.0
```

FOR MAIZE COST 900,0

AT POWER COST 90,0

VARIOUS FUEL VALUES

TONNE	80.00	85,00	90.00	95,00	100,00
50,00	22385,997	22135,997	21885,995	21635,997	21385,997
60,00	29895,995	29595,995	29295,995	28995,993	28695,993
70,00	37405,993	37055,993	36705,993	36355,993	36005,993
80,00	44915,989	44515,989	44115,989	43715,989	43315,993
90,00	52425,993	51975,993	51525,993	51075,993	50625,989
100,00	59935,989	59435,985	58935,985	58435,989	57935,985

AT POWER COST 95,0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	22135,997	21885,995	21635,997	21385,997	21135,997
60,00	29595,995	29295,995	28995,993	28695,993	28395,997
70,00	37055,993	36705,993	36355,993	36005,993	35655,993
80,00	44515,989	44115,989	43715,989	43315,993	42915,993
90,00	51975,993	51525,993	51075,993	50625,989	50175,989
100,00	59435,985	58935,985	58435,989	57935,985	57435,989

AT POWER COST 100,0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	21885,995	21635,997	21385,997	21135,997	20885,997
60,00	29295,995	28995,993	28695,993	28395,997	28095,995
70,00	36705,993	36355,993	36005,993	35655,993	35305,993
80,00	44115,989	43715,989	43315,993	42915,993	42515,989
90,00	51525,993	51075,993	50625,989	50175,989	49725,989
100,00	58935,985	58435,989	57935,985	57435,989	56935,985

FOR MAIZE COST 950,0

AT POWER COST 90,0

VARICUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	19885,997	19635,997	19385,997	19135,997	18885,997
60,00	26895,995	26595,993	26295,995	25995,993	25695,993
70,00	33905,993	33555,993	33205,993	32855,995	32505,997
80,00	40915,993	40515,993	40115,993	39715,993	39315,993
90,00	47925,993	47475,989	47025,989	46575,989	46125,989
100,00	54935,989	54435,985	53935,985	53435,989	52935,985

AT POWER COST 95,0

VARICUS FUEL VALUES

TONNE	80.00	85,00	90,00	95,00	100,00
50,00	19635,997	19385,997	19135,997	18885,997	18635,997
60,00	26595,993	26295,995	25995,993	25695,993	25395,995
70,00	33555,993	33205,993	32855,995	32505,997	32155,993
80,00	40515,993	40115,993	39715,993	39315,993	38915,997
90,00	47475,989	47025,989	46575,989	46125,989	45675,993
100,00	54435,985	53935,985	53435,989	52935,985	52435,989

AT POWER COST 100,0

VARICUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	19385,997	19135,997	18885,997	18635,997	18385,997
60,00	26295,995	25995,993	25695,993	25395,995	25095,997
70,00	33205,993	32855,995	32505,997	32155,993	31805,995
80,00	40115,993	39715,993	39315,993	38915,997	38515,993
90,00	47025,989	46575,989	46125,989	45675,993	45225,993
100,00	53935,985	53435,989	52935,985	52435,989	51935,985

FOR MAIZE COST 1000,0

AT POWER COST 90,0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	17385,997	17135,997	16885,997	16635,998	16385,998
60,00	23895,995	23595,995	23295,997	22995,997	22695,997
70,00	30405,995	30055,995	29705,995	29355,993	29005,995
80,00	36915,997	36515,993	36115,997	35715,993	35315,993
90,00	43425,993	42975,993	42525,993	42075,989	41625,989
100,00	49935,989	49435,993	48935,989	48435,993	47935,989

AT POWER COST 95,0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	17135,997	16885,997	16635,998	16385,998	16135,998
60,00	23595,995	23295,997	22995,997	22695,997	22395,995
70,00	30055,995	29705,995	29355,993	29005,995	28655,997
80,00	36515,993	36115,997	35715,993	35315,993	34915,993
90,00	42975,993	42525,993	42075,989	41625,989	41175,993
100,00	49435,993	48935,989	48435,993	47935,989	47435,989

AT POWER COST 100,0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	16885,997	16635,998	16385,998	16135,998	15885,997
60,00	23295,997	22995,997	22695,997	22395,995	22095,995
70,00	29705,995	29355,993	29005,995	28655,997	28305,995
80,00	36115,997	35715,993	35315,993	34915,993	34515,993
90,00	42525,993	42075,989	41625,989	41175,993	40725,993
100,00	48935,989	48435,993	47935,989	47435,989	46935,993

FOR MAIZE COST 1100,0

AT POWER COST 90,0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	12385,998	12135,999	11885,999	11635,999	11385,999
60,00	17895,997	17595,999	17295,997	16995,997	16695,999
70,00	23405,997	23055,997	22705,997	22355,995	22005,997
80,00	28915,997	28515,997	28115,997	27715,995	27315,995
90,00	34425,993	33975,997	33525,997	33075,995	32625,995
100,00	39935,997	39435,997	38935,993	38435,993	37935,997

AT POWER COST 95,0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	12135,999	11885,999	11635,999	11385,999	11135,998
60,00	17595,999	17295,997	16995,997	16695,999	16395,999
70,00	23055,997	22705,997	22355,995	22005,997	21655,999
80,00	28515,997	28115,997	27715,995	27315,995	26915,997
90,00	33975,997	33525,997	33075,995	32625,995	32175,993
100,00	39435,997	38935,993	38435,993	37935,997	37435,997

AT POWER COST 100,0

VARIOUS FUEL VALUES

TONNE	80,00	85,00	90,00	95,00	100,00
50,00	11885,999	11635,999	11385,999	11135,998	10885,999
60,00	17295,997	16995,997	16695,999	16395,999	16095,999
70,00	22705,997	22355,995	22005,997	21655,999	21305,997
80,00	28115,997	27715,995	27315,995	26915,997	26515,997
90,00	33525,997	33075,995	32625,995	32175,993	31725,997
100,00	38935,993	38435,993	37935,997	37435,997	36935,997